Technical Writing

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PREFACE

This book had its inception in our need for a logical bridge between the professional writing of scientists and engineers and the content of a course for students of technical writing. Certain widespread practices had developed in such courses, as we knew both from personal experience and from such published studies as A. M. Fountain's *A Study of Courses in Technical Writing* (1938), the American Society for Engineering Education's report on *Instruction in English in Engineering Colleges* (1940), and M. L. Rider's *Journal of Engineering Education* article, "Some Practices in Teaching Advanced Composition for Engineers" (1950). We felt that many of these practices were unquestionably proving their value, but about others we weren't sure, and there seemed to be no clearly established basis upon which to decide about them. The difficulty was partly that the limits of the subject were uncertain; apparently nobody had ever seriously explored the concept of technical writing with the purpose of trying to say precisely what technical writing is. There were, of course, numerous systems of classification of articles and reports; but, unfortunately, these systems were dissimilar at many points and were often more puzzling than helpful in relation to our question of what materials and instruction were most needed by our students.

In an effort to find practical solutions to the problems just noted, as well as to others not mentioned, we undertook three investigations. We began by seeking examples of reports and articles, and expressions of opinion about important problems; altogether we incurred an indebtedness to over three hundred industrial and research organizations in making our survey. We also worked out, in writing, a theory of what technical writing is (later published as Circular No. 22 of The University of Texas, Bureau of Engineering Research, under the title, *The Theory of Technical Writing*). Thirdly, we studied the content

and organization of college courses in the subject. The content of this book rests primarily upon these investigations, together with numerous other studies of a more limited scope. Perhaps it is proper to say here that these investigations did not constitute our introduction to the subject, since we had both had considerable experience in the field, in the capacity of teachers and editors. On the other hand, we did try hard to avoid letting the particularities of our personal experience affect the conclusions we drew from these systematic studies. We realize, of course, that the nature of our own experience, both academic and non-academic, has no doubt been reflected in our text; and if in spite of the good counsel and abundant materials furnished to us we have fallen into error, the fault is entirely our own. We do believe, however, that our methods have been sound; we hope that our book is sound too.

Perhaps we should add, about ourselves, that our collaboration has extended to all parts of the text. Almost every page of it represents a joint effort.

A few comments on the text itself need to be made here. As we said, the organization of the book was determined by a study of the needs and practices of courses in technical writing, as well as by the internal logic of the subject matter. One problem, however, resisted solution: we could not find any clear grounds on which to decide when to introduce certain elements of our subject that would not themselves usually be the basis of writing assignments. Section Three (Transitions, Introductions, and Conclusions) and Section Five (Report Layout) are chiefly involved, although the same difficulty exists with Chapter 3 (Style in Technical Writing). We have no pat answers as to how these elements should be introduced into a course. On the contrary, we believe that a suitable decision can be made only by the instructor.

We should also like to remark that we are aware we have sometimes been blunt in criticizing quoted materials. We hope all readers of the book will understand that these materials were not prepared especially for our use. They are, instead, routine products, and many of them were doubtless written under great pressure. We have been critical in order to help students learn, not because of any fancied superiority to the writers whose work we criticize.

We regret that a complete list of those organizations and persons who have helped us is too long to present here. We are deeply grateful to all of them, and we have acknowledged our specific indebtedness to many in the text. A few have requested anonymity. Our greatest single debt is to Mr. John Galt, Manager, Phenolic Products Plant, Chemical Materials Department, General Electric Company, Pittsfield, Massachusetts. Mr. Galt permitted us to quote the extremely

interesting manuscripts in Appendix B. We should like to mention also The Civil Aeronautics Administration, Technical Development and Evaluation Center; and the Research Laboratories Division, General Motors Corporation. Mr. W. E. Kuhn, Manager of the Technical and Research Division, The Texas Company, deserves special thanks for repeated favors.

Austin, Texas G. M.
January, 1954 J. W.

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section one

Preliminary Problems

The purpose of this first section is to point out some fundamental principles that will be applicable throughout the rest of the book. In Chapter 1 a definition of technical writing is given, the major subdivisions of the subject are stated, and some opinions about the importance of technical writing are quoted from distinguished engineers. Chapter 2 is a short summary of basic concepts that will later be presented in detail. Chapter 3 is concerned with the elements of style, and Chapter 4 is a review of logical organization in terms of outlining and abstracting.

1

Introduction

The purpose of this book is to discuss the principles and practice of the kind of writing required of engineers and physical scientists as part of their professional work. The reader to whom the book is directed is primarily the student of engineering who has had enough training in the fundamentals of composition to profit from consideration of some of the problems of technical writing.

In this chapter we shall first explain what technical writing is, and then go on to discuss what the engineer is required to write and what aspects of writing he particularly needs to study. At the end of the chapter will be found a series of statements by experienced engineers on the part that writing plays in the work of the engineer.

What Technical Writing Is

Although one of the obvious characteristics of technical writing is that it is concerned with technical subject matter, it would be very difficult to say precisely what a technical subject is. For our purposes, however, it will be sufficient to say merely that, as we use the term, a technical subject is one that falls within the general field of science and engineering. The subject matter of technical writing is science and engineering.

Technical writing has other characteristics besides its subject matter, of course. One of these characteristics is its "formal" aspect—a term which is also hard to define but is easy to illustrate. There are, for example, certain forms (hence the word "formal") of reports, like progress reports, that are used in technical writing. There are certain forms of style and diction used. There are certain forms of graphic aids (e.g., sketches, graphs, flowsheets).

Another characteristic of technical writing is the scientific point of view. Ideally, technical writing is impartial and objective, clear and accurate in the presentation of facts, concise and unemotional. In practice, naturally, some of these qualities are often lacking, particularly clarity and conciseness. An additional fact about point of view is that technical writing is usually designed for a specific reader or group of readers, perhaps the staff of a certain research group, rather than for a great mass of readers, as is newspaper writing.

The last major characteristic is what can be called the special techniques of technical writing. What this means can easily be explained by an analogy. When a person decides he would like to write short stories, he soon finds himself studying, among other things, how to write dialogue. No one questions the logic of this. But the short-story writer is not the only one who uses dialogue; probably we all occasionally write down some conversation, in a letter or elsewhere. Nevertheless, the short-story writer uses dialogue more than most people, and it is very important in his writing. Therefore he must know all he can about it. Similarly, there are certain techniques that the technical writer uses particularly often. They do appear in other kinds of writing, but most of them not so frequently, and not so often as such an important part of the whole. Consequently, the technical writer should learn all he can about these techniques. The most important are description of mechanical devices, description of processes, definition, classification, and interpretation. Each one of these writing problems is complex enough to need careful attention, and each one of them appears frequently in technical writing.

It should be clearly understood that these special techniques are not types of technical reports. Several of them may appear in a single report; but for an entire report to be nothing more than, say, the description of a mechanical device would be unusual. Again, it is like dialogue in a short story, which may take an important part, but is seldom the whole story.

In summary, then, technical writing can be defined as follows:

A. Technical writing is writing about scientific subjects and about various technical subjects associated with the sciences.

B. Technical writing is characterized by its use of scientific and technical diction, certain types of graphic aids, certain conventional report forms, and so forth.

C. Technical writing is ideally characterized by the maintenance of an attitude of impartiality and objectivity, by extreme care to convey information accurately and concisely, and by the absence of any attempt to arouse emotion.

D. Technical writing is writing in which there is a relatively high concentration of certain complex and important problems of writing technique, in particular description of a mechanical device, description of a process, definition, classification, and interpretation.

What the Engineer Is Required to Write

The question of what the engineer is required to write can be answered briefly by saying that he writes letters, reports, articles, and books. Perhaps it is stretching a point to say that he is required to write articles and books. Such documents are clearly a necessary part of the work of the engineering profession as a whole, however, and they do not write themselves. As a matter of fact, although there are practicing engineers who devote most of their time to writing, there are others who never, or hardly ever, write anything at all. There are also engineers who almost never use mathematics in their work. On the other hand, the more responsible a position the engineer holds the more likely he is to need skill in writing and in mathematics. It is probably safe to turn this proposition around and say that the more skill in writing and mathematics an engineer has the more likely he is to be given a position of responsibility.

The young engineer just out of school is not often called on for more than what might be called routine writing, not greatly different from the simple laboratory reports he wrote in school. He is frequently used primarily as an instrument for the collection of data, or as an overseer of simple operations. He might, for instance, be assigned to check the quality control in the production of a certain type of carburetor. If his data show that the quality control is not satisfactory, then what? Perhaps his boss will examine the data and then write a report to his own superior recommending corrective measures. The top man, the executive, may be scarcely aware of who it was that collected the basic information, and if he does know he may feel that any one of a dozen of his other young men could have done as well. On the other hand, the young engineer might be asked to include in his own report suggestions for correcting the situation. Now, if his suggestions are sound, it becomes a matter of considerable interest to

him whether his report goes on up to the top executive with his own name on it, or is rewritten and goes up with somebody else's name in addition to, or in place of, his own. His chief hope for attracting the personal interest of the executive may lie in getting just such reports up to him. But the young man's immediate superior is not going to risk sending on poorly written reports which might arouse the top executive's displeasure.

As the young engineer wins promotion he finds his judgment, as opposed to his mere data-recording ability, increasingly in demand. The reports he is asked for are more and more concerned with decisions, some of them decisions on action to be taken, some of them decisions as to the soundness of conclusions about theoretical problems. Customers of his company write him letters asking for advice about their technical problems, and he writes letters in reply. For other men in his own organization he must frequently write letters and reports, and both informally and formally carry on oral discussions of joint problems. His superiors call for progress reports at regular intervals on the work he is doing, and for long reports at important stages. He is asked to address chapters of professional organizations. If he is ambitious to establish a reputation, he submits articles to professional journals. And if fortune and ability conspire he finds himself in the course of years noting with interest that one of the young men he recently hired is sending up some very sensible and clean-cut reports.

We do not want to seem to say that an engineer's chances of success are in direct ratio to his ability to write well. However, the comments at the end of this chapter clearly indicate that the ability to write well is highly important.

It was pointed out that the technical man will probably have to write reports, and letters, and may write articles and books. But the bulk of his writing is doubtless in the form of reports. What is a report? Again, there is little point in attempting an exact definition. Perhaps as good a definition as any is that a report is a piece of technical writing designed to meet a specific need. In the introduction to Section Four you will find a list of thirty-odd "types" of report. Many of these types differ from each other only in minor details, and in some cases probably in none at all. What happens is that a group of technical men decide that they need to have information about certain types of projects written up in a certain form, and perhaps at certain stages of progress, and so they make up some rules and give this "type" of report a name—perhaps "preliminary," or "partial," or "shop," or "test." That is exactly what they should do. If the form

of report they devise serves their purposes, no more could be asked.

There are nevertheless a few types of reports that are pretty well standardized. Three that deserve mention are the progress report, the recommendation report, and the form report. They will be discussed in detail in Section Four.

Aspects of Writing Which the Engineer Particularly Needs to Study

In the most elementary terms, technical writing can be broken down into two parts, or aspects: (1) the "end products" (like reports and letters), the concrete "package" that you deliver; (2) the skills that enter into the preparation of the end product. This distinction, while on the whole quite vague, is useful in pointing out specific aspects of writing that are of particular importance to the engineer, and which we shall accordingly be concerned with in this book.

The important "end products" of technical writing are these:

1. Business letters
2. Various kinds of reports
3. Articles for technical journals—and possibly books
4. Abstracts
5. Oral reports
6. Graphic aids

It is quite possible that you may never be interested in writing for technical journals, but the other items in the list above are all part of the routine work of the engineering profession. Oral reports seem less tangible than the others, perhaps more like a skill than a "product," but of course the spoken word has as real an existence as the written. And we should add that "oral reports" refers not only to formal speechmaking, but also to relatively informal discussions of technical problems. The heading "graphic aids," by which we mean graphs, drawings, and so forth, also looks a little odd in this list. Are graphic aids a skill, an end product, or neither? Whatever they are, of this you may be sure: it is good to know about them. It doesn't particularly matter what we call them.

The skills which deserve particular attention are the following:

1. Special techniques of technical writing
2. Style
3. Introductions, transitions, and conclusions
4. Outlines
5. The layout, or format, of reports

The special techniques of technical writing have already been commented on. The other items in the list above need a brief explanation.

The word "style" usually suggests an aesthetic quality of prose, a quality determined by the relative smoothness or awkwardness with which sentences are put together. Numerous eminent scientists and engineers have developed a splendid prose style. Naturally we should like to encourage you to develop a good style; but above all else we shall emphasize clarity. Since technical writing is by definition a method of communicating facts, it is absolutely imperative that it be clear. At the same time, the nature and complexity of the subject matter of technical writing often involve the writer in particularly difficult stylistic problems. These problems will be discussed in the chapter on style. One other important aspect of style in technical writing is point of view. In brief, the point of view should be scientific: objective, impartial, unemotional.

The third item is introductions, transitions, and conclusions. The problem here is to learn to tell your reader what you're going to tell him, then to tell him, then to tell him what you've told him. This skill is one of the most important a technical writer, or any writer, can possess.

The fourth element is outlines. A more accurate phrase might be, "The theory of organizing your writing," because that is what we are really interested in. Outlines, like dentists, are popularly associated with pain, but both serve an admirable purpose. We shall try to make our outlines as painless as possible.

And the fifth and last element, the layout of reports, has to do with such matters as margins, spacing, subheads, the title page, and the like.

Doubtless you have noticed that grammar and punctuation were not included in either of the two lists above. The reason for the omission of these fundamentals is that they are not properly part of the formal subject of technical writing. Constant attention to these fundamentals is nevertheless a necessity. We suggest that you get a good handbook of English, if you do not already have one, and—if you have not already done so—develop the habit of using it. Professional writers do no less.

Altogether, the topics which have been listed are those that are most important to the beginner in technical writing. It should be understood, however, that they are not the only aspects of technical writing that deserve attention. There will be others, for instance the

handling of footnotes and bibliography, and the use of the library, that will be discussed in the appropriate place.

Our purpose has been to state in the simplest terms possible what the study of technical writing involves. Setting up a practical course of study naturally requires rearrangement and regrouping of the topics listed. Reference to the table of contents will indicate how that has been done in this text.

Comments by Some Eminent Engineers

The purpose of this concluding section of the chapter is simply to provide an opportunity for you to read the opinions of some distinguished engineers on the relative part played by writing in professional work.

Mr. John Mills, a well-known engineer and for a long time Director of Publications for the Bell Telephone Laboratories, wrote in *The Engineer in Society:*

> [Young engineers] do not realize that their experiments or calculations are but part of their work and that there is no fruition until their conclusions are accepted. They hide their lights under a bushel and, years later, they find themselves the fags of their profession. If an investigation or experiment is honestly carried out, no data fudged, the set-up critically scrutinized, and the conclusions honestly drawn without regard to credit or discredit, or to the particular "party line" of the department, then these conclusions representing a fraction of the life of the engineer are sometimes worth presenting in favorable arrangement. If engineers won't do that, they may misfire and bring down nothing, except upon their heads the obloquy of disregard. There is nothing that smothers the creative spark in a young engineer more quickly than disregard of his best honest efforts; and nothing that I know makes such disregard more inevitable than an inability to present his work persuasively.*

In the same key is the following excerpt from a letter written by Mr. B. M. Filbert, of the Research and Development Division, Refining Department, Humble Oil and Refining Company. He says:

> It has been our experience that many technical graduates are inadequately informed as to the need for effective writing and the proper techniques for accomplishing it; industrial technical activities are primarily of the nature of staff functions and they are completely useless unless the results are presented in sufficiently interesting and convincing fashion to prompt positive action on the part of the operating management.

* John Mills, *The Engineer in Society* (New York, 1946), pp. 163–164. Reprinted by permission of D. Van Nostrand Company, Inc., publishers.

In an interesting and significant discussion of some of the writing problems in the Research Laboratories of General Motors Corporation, T. O. Richards and Ralph A. Richardson stated:

> Every technical man has use for the ability to do technical writing of some type. He may be employed in industry, in government laboratories, in educational work, or in the hundreds of jobs that the engineer and scientist now holds. The only fault we can find with his work is that he never does enough writing. Writing is usually difficult for him and takes time which he frequently feels could be better spent in experimentation. In fact, it is much easier to perform the experiment than it is to write a report of it.*

And Mr. Charles Kettering, retired Director of the General Motors Research Laboratories, and long a persuasive advocate of the importance of English to engineers, has said:

> Success in engineering and research depends as much upon the ability to present an idea convincingly as it does upon the ability to perform calculations or experiments. . . . Scientific men too often look upon writing reports or making talks as an irksome part of their job and do as little of it as possible. Engineering work is not finished until the results are clearly recorded and presented to others.†

Still another engineer, Mr. E. C. Shuman, Director of Research, Kaylo Division, Owens-Illinois Glass Company, says:

> . . . when I was a student, there was strong admonition that one of the engineer's greatest weaknesses was a profound lack of ability to write and speak effectively—that reports were an engineer's means for presenting facts. I believed the criticism then, and am sure of its validity now.‡

It has often been argued that English is as much an engineer's tool as mathematics and the like. Here a consulting engineer, Dr. J. A. L. Waddell, says:

> There is a general opinion among engineering students that the study of one's own language is not of great importance, as compared with that of mathematics and technics; but, believe me when I tell you that this idea is fundamentally and absolutely wrong. To become a successful engineer, one must be capable of persuading others concerning his ability to do contemplated work; he must be able to draft his specifica-

* T. O. Richards and Ralph A. Richardson, *Technical Writing* (Detroit, Mich., 1941), p. 7.
† Charles Kettering, "The Importance of English to the Engineer," *Journal of Engineering Education, 28* (January, 1937), 442.
‡ E. C. Shuman, "Some Modifications in Approach to Teaching Engineers," *Journal of Engineering Education, 37* (January, 1947), 448.

tions and contracts with clearness; and his reports need to be not only plain, sound, and convincing, but also pleasing. . . .*

And just as emphatic is the statement of another consulting engineer, Mr. D. W. Mead, who says, "There is no profession in which the ability to express the writer's meaning in clear and unmistakable language is more important than in engineering." †

As to the importance of good reports in determining an engineer's success, consider these two statements, the first by Mr. Luis DeFlorez:

> Technical students, as a rule, do not realize the importance of writing a good report or technical paper. Neither do they realize the necessity of speaking convincingly. Yet their careers are often determined by these faculties.‡

The second statement, by Mr. E. L. Robinson of the General Electric Company, reads as follows:

> In connection with every engineering work of any importance, there is always a time at which its eventual success, or its immediate abandonment, depends on the preparation of a convincing report. Thus the ability to express facts clearly and convincingly . . . contributes greatly to the personal success of an engineer.§

The following rather long quotation, coming from the head of a large corporation who prefers to remain anonymous, not only emphasizes the fact that engineers are too frequently not skillful at writing but also suggests what some of the troubles are:

> In my experience many college trained men do not know how to present the results of their work in straightforward and readable reports. All too often the purposes, observations, and results of days of experimentation are obscured by the indifferent organization and irrelevant detail of muddled writing. . . . Many technical graduates have never had thorough training in the techniques of technical or other exposition. Consequently they must either train themselves after graduation or be under a handicap in the competition for advancement in industry.
>
> Perhaps the primary deficiency in technical report writing is lack of organization. . . . The writers generally show some training in grammar and sentence structure, but an ignorance of the fundamental structure of the technical report.
>
> A second major deficiency, from the standpoint of an industrial

* In A. A. Potter, "The Place of English in the Engineering Curriculum," *Journal of Engineering Education*, 27 (April, 1937), 587.
† In J. L. Vaughn, "Some Opinions of Engineers on the Importance of English," *Journal of Engineering Education*, 28 (March, 1938), 487.
‡ *Ibid.*, p. 483.
§ *Ibid.*, p. 485.

> organization, is the inability to present technical material in language a layman can understand. Scientific terminology may be explicit but it does not furnish a busy executive with an understandable basis for action.*

Another department head of a large corporation, concerned with the same problem, says:

> My observation of report writing by our staff is that the men have difficulty in presenting their subject because of limited vocabulary, lack of ability to express themselves concisely yet clearly, and inability to emphasize the important parts of their reports in such a manner that they attract attention. Many reports have to be reread in order to sift the important from the unimportant.†

In the same vein are the following quotations taken from an editorial by Walter J. Murphy in *Industrial and Engineering Chemistry* in which he quotes several industrial leaders.‡ Among those cited, Mr. Thomas H. Vaughn, research director of Wyandotte Chemical Corporation, said, "Particularly in the field of report writing do we find the average graduate to be woefully lacking. In our organization we are stressing the value of report writing and have finally come to consider it an important subject in relation to a man's advancement in the organization." Mr. Willard Dow, president of the Dow Chemical Company, was quoted as saying, "The average engineer is most inadequately equipped to express himself in the English language. I think I speak on a subject which has been overlooked and underrated." And Mr. Emil Ott, research director for the Hercules Powder Company, commented, "More thorough training in English composition and other courses designed to train students to organize material and present it effectively is undoubtedly required."

We shall close this series of selected comments with one that ends on a somewhat more optimistic note than those quoted above. In a letter from Mr. W. E. Kuhn, Manager of the Technical and Research Division of the Texas Company, there is this statement: "Our observations have shown that few technically trained people are born naturally good technical report writers, but it is not beyond the realm of reason to expect that a large number of those in the technical field

* *The News Letter* (CEA), *9* (September, 1947), 1. Reprinted by permission of the College English Association.

† *Ibid.*, p. 5.

‡ Reprinted by permission of the copyright owner, the American Chemical Society. Walter J. Murphy, *Industrial and Engineering Chemistry, 39* (July, 1947), 807.

can be trained to be acceptable report writers if suitable training is afforded them."

We have quoted a rather large number of comments because we hope that they will make it clear that engineers in professional work, and especially those who employ engineers, are the most ardent exponents of careful, practical training in technical writing.

2

Five Basic Principles of Good Technical Writing

Chapter 1 was concerned with the general subject and plan of this book, and with indicating the importance of writing in the professional work of the engineer and scientist; the present chapter, consisting only of what appears on this and the following page, is devoted to a highly condensed preliminary statement of five basic principles that will later be presented in detail. There are many more than five principles involved in good technical writing, but the five stated below are so important that they may be taken as a foundation on which further development rests.

1. Always have in mind a specific reader, real or imaginary, when you are writing a report; and always assume that he is intelligent but uninformed.

2. Before you start to write, always decide what the exact purpose of your report is; and make sure that every paragraph, every sentence,

every word, makes a clear contribution to that purpose, and makes it at the right time.

3. Use language that is simple, concrete, and familiar.

4. At the beginning and end of every section of your report check your writing according to this principle: "First you tell the reader what you're going to tell him, then you tell him, then you tell him what you've told him."

5. Make your report attractive to look at.

You will find that these principles are involved in one way or another with practically everything that is said throughout the rest of this book.

3

Style in Technical Writing

Introduction

The purpose of this chapter is to point out the characteristics of a desirable technical style. Before we set down any suggestions or "rules" for you to follow in achieving a desirable style in your reports, however, we need to explore the meaning of the term "technical style," or—to begin with—the meaning of the term "style" itself.

You probably recall hearing a discussion of style in courses in literature, and perhaps have been asked to analyze the style of writers whose work you were reading. Your experience was not unusual if you had considerable difficulty in making such an analysis. Style is hard to describe simply and directly. The whole always seems greater than the sum of the parts. On the other hand, it isn't particularly difficult to describe the impression or effect a style of writing makes. It's like the personality of an acquaintance. We can readily judge the total impression he makes as energetic and cheerful or nervous and excitable, though we may never be able to list all the traits that create this impression.

The difficulty of arriving at an exact definition of style may be responsible for the many colorful aphoristic definitions that writers

and literary critics have invented. Jonathan Swift said that style is "proper words in proper places"; Lord Chesterfield, that it is "the dress of thoughts"; and the Comte de Buffon, that "style is the man." We would say simply that style is the way you write, and this means the way you put words together in sentences, the way you arrange sentences into paragraphs, and the way you group paragraphs to make a whole composition.

Technical style, then, is the way you write when dealing with technical subject matter. But because of the specialized nature of technical subject matter, the functions which reports about it serve, and certain well-established conventions or traditions relating to its presentation, we can characterize technical style more explicitly. We can say that technical writing style is distinguished by a calm, restrained tone, by an absence of any attempt to arouse emotion, by the use of specialized terminology (though every specialized field has its own distinctive terms, of course), and by an accepted convention of the use of abbreviations and symbols.

Objectives of This Chapter

Neither aphoristic comments nor descriptive definitions help much, however, when it comes to the practical problem of how to write a satisfactory style. What you will want to know is what is desirable in report-writing style and how it may be achieved. Our purpose in this chapter, therefore, is to consider the most desirable characteristics of an effective style for reports, the problems which give inexperienced writers most trouble, and the accepted conventions for using abbreviations, symbols, and numbers, as well as some miscellaneous matters of usage. In carrying out these purposes we have divided the chapter into two parts. In Part One we shall discuss, in the following order, the problems of reader adaptation, maintenance of the scientific attitude, the construction of sentences that say what they are supposed to say, precision in the use of words, and the structure and length of sentences and paragraphs. In Part Two we shall turn to problems of common faults of usage and to the mechanics of style.

PART ONE

Reader Adaptation

Unlike much commercially published material, reports are written for a specific reader or group of readers. The writer usually knows his readers personally, or knows who they are well enough to

make a reasonable estimate of what they know of the subject he is writing about. Furthermore, besides knowing *who* will read his report, he knows *why* they will read his report. Knowing the reader and the purpose of a report permits what is generally called "reader adaptation," that is, styling the report to suit the needs, knowledge, interests—and prejudices, it may be—of the reader.

Mr. C. C. Furnas, Director of the Cornell Aeronautical Research Foundation, has said:

> In my experience I have had rather lengthy struggles in the report writing activities, both from the teaching and the writing end, and for whatever it may be worth, I would like to pass on the two key ideas which I feel to be most important:
>
> 1. The first and most important job of the man writing a report is to visualize his audience and put himself in the position of the man who is going to read it.
>
> 2. He should always assume that his audience is intelligent, but uninformed, on a particular subject.*

In a memorandum on report writing to its engineers (see Appendix C) The Texas Company states that "it is imperative that the report be written entirely from the viewpoint of the reader and be clearly intelligible to him." John A. Miller, of the General Engineering and Consulting Laboratory, General Electric Company, states that

> the most important step in the development of technical writing ability is to cultivate the habit of putting yourself in the position of the reader of what you write. [Consider] who he is, what his interests are, what he already knows about the subject you intend to discuss, and what he wants to know. Then, as you write, ask yourself what questions will arise in the mind of the reader and whether you are answering them.†

Another large company, in a pamphlet designed for its engineers, says:

> The report is the final result of a contract, as far as the Client is concerned, and therefore, of extreme importance. . . . It should be remembered that the report may be given to men who are not familiar with the work we had to do before the report could be written.

The Scientific Attitude

Although it is necessary to write with the interests of the reader clearly in mind, it is also necessary to keep the style of the

* Personal letter.

† "Technical Writing—an Easily Acquired Skill," *Civil Engineering, 18* (May, 1948), 300. This is a publication of the American Society of Civil Engineers.

writing strictly impersonal. One of the distinguishing characteristics of technical style is an absence of any attempt to arouse emotion. The point of this is, of course, that personal feelings must be excluded so that attention can be concentrated on the concrete facts involved in the subject matter. The two factors on which achievement of this objectivity chiefly depends are the use of the proper grammatical voice and the maintenance of a calm, restrained manner.

Long-established convention dictates that formal reports be written in the third person, generally in the passive voice. The theory is that exclusion of personal pronouns produces a style consistent in tone with objectivity, and that the use of the passive voice permits placing emphasis on the subject matter of the report rather than upon the human beings who worked with (or on) the subject matter. The following two sentences illustrate the differences between the styles:

1. *Personal, Active Voice:*

I set up the testing equipment in the laboratory and ran three tests before drawing the conclusions herein set down.

2. *Impersonal, Passive:*

The testing equipment was set up in the laboratory, and three tests were run before the conclusions herein set down were drawn.

A third possibility that many regard as more effective than either of these is the use of the third person, active. Consider this example: "The technicians set up the testing equipment in the laboratory and ran three tests before drawing the conclusions herein set down." In this sentence, an objective, third-person noun is substituted for the personal pronoun in the first illustration. Most readers agree that active verbs are more vivid and emphatic than passive verbs; hence the preference among many for this style. Still another possibility that permits impersonality of tone, if properly handled, is the use of the first-person plural pronoun "we." Used without any real personal reference, the first person plural style can be objective enough, but may sound stilted and unnatural unless there is actually a plural antecedent. Consider the following sentence: "In this experiment, we found that these bearings would not stand up under temperatures above 1500 degrees Fahrenheit." "We" in this sense may stand for a research organization, such as a testing laboratory, and taken in this way is acceptable. But if the only possible referent of "we" were an individual author, it would sound absurdly pompous. (This problem is treated at some length in the chapter on process exposition [Chapter 7]; we suggest that you refer to the discussion there.) Whatever

the merits of passive versus active voice, it is a fact that most technical writing is written in the passive voice, and most organizations expect reports to be written in that style.

Impersonality of style, or objectivity of tone, is not altogether a matter of employing the third person or of using the passive voice, however. An undesirable tone can easily be manifested through any style. A writer might say, for instance: "There can be no doubt that this product is infinitely superior to all others on the market; as a matter of fact, the others are worse than useless—they are shoddily made and placed on the market, it would appear, by an entirely unscrupulous group of shysters." This sentence is written in the passive voice, without personal pronouns. But it is not objective in tone. A preferable version is this: "Product A is superior to all other products tested, as the data show."

So, in addition to leaving out those elements which are personal in a purely grammatical way, it is also necessary to exclude words and phrases of an emotional sort unwarranted by the subject matter. "Dignity" and "restraint" are the words ordinarily used to describe the tone desired.

Although personal pronouns will ordinarily have to be excluded in formal reports to maintain impersonality of style, they need not be avoided in informal letter reports and memoranda, where they are natural and appropriate. Phrases like "the author," or "the writer" would seem stilted in these circumstances.

Making Sentences Say What You Mean

Besides giving attention to the needs of the reader and maintaining an objective manner, the technical writer must be certain that he is expressing his thought accurately. A great deal of bad writing results from the writer's failure to think carefully enough about what his sentences actually say. Perhaps this fault is a habit of mind as much as anything; usually when a person is shown that a sentence he has written doesn't make good sense he recognizes the error at once and complains that he can't understand why he didn't see it before. However this may be, one of the essentials of learning to write well is certainly the development of a habit of critically analyzing one's own sentences.

The kind of bad writing we are concerned with here is illustrated by the following passage:

> A problem usually arising in the minds of laymen considering solar heating for their home is the glare which might result from the use of large areas of glass. Actually, however, *just the reverse* has been found

> to be true. Large windows, while admitting more usable light, *produce less* than several small openings.

The italicized phrases don't convey the meaning the author intended. Just the reverse of what? Produce less what?

Here is a second illustration of the same sort of bad writing:

> The greatest problem which is found due to using large panes of glass is caused by the fact that glass is an excellent conductor of heat.

There are a lot of unnecessary words in this sentence, but that obviously isn't the worst blunder in it. The worst blunder is the statement that glass is an excellent conductor of heat. The author knew very well that glass is a poor conductor, but he had a picture in his head of a lot of heat coming in through the window pane, and he knew the picture was correct. So he wrote down some words that had to do with the transfer of heat and was satisfied. What he was satisfied with was the picture in his head, which was a good picture. He paid little attention to the words. When he was later shown the words he saw at once that they were wrong.

To avoid mistakes of this kind, put aside a piece of writing for as long as you can after finishing the first draft. Leave it until you can see the words instead of the pictures in your head. For some people, reading aloud is a help in spotting faulty passages. Ultimately, of course, everything depends on using words which mean precisely what you want to say.

Precision in the Use of Words

Precision in the use of words requires the technical writer to acquire an exact knowledge of the meanings of words, to avoid words that—in a given context—are vague, to leave out unnecessary words, to use simple words wherever possible, and to avoid technical jargon.

Knowing What Words Mean. It is unfortunately true that many words are used incorrectly in technical writing. A survey of errors of usage in reports written by senior students of chemical engineering at the University of Texas, for example, showed that the words "affect" and "effect" are commonly confused by a majority of the students. "Imply" and "infer" are confused almost as often. The word "unique" is a pitfall for many. We suggest you look it up; there's no other word like it. The difference between "per cent" and "percentage" evades many writers. If there's a number before it the word is "per cent": "We agreed that 90 per cent is a large percentage."

Avoiding Vague Words. Most often, however, precision of

meaning is lost not through outright error in the use of terms but by the use of words which, although not incorrect, do not convey the exact meaning demanded. For example, words like "connected," "fastened," or "attached" are used instead of terms that more accurately denote the nature of a connection—terms like "welded," "soldered," "bolted," "spliced." Of course there is nothing wrong with any of the words mentioned; it is in the way the words are used that trouble may develop.

LEAVING OUT UNNECESSARY WORDS. Words which serve no useful purpose should be rigorously weeded out of your reports during the process of revision. A comprehensive discussion of the ways in which words can be, and are, unnecessarily used lies far beyond the scope of this chapter. We shall discuss only a few instances. On the other hand, the positive principle we want to establish is probably demonstrated as well by a few examples as it would be by a great many. This principle is simply that you should take a hard look at every word in a sentence to make sure that it is there for a good reason.

There are, to start with, various pitfalls associated with the use of abstract words like "nature," or "character," or "condition." (Please remember that it is not the word itself but the incorrect use of the word that we are criticizing.) Consider the following sentence: "The device is not one of a satisfactory description." What does the word "description" contribute to the sentence? Nothing at all. It is a useless appendage. The sentence might better have read: "The device is not satisfactory." Here are some other examples:

> The principal reason for this condition is that the areas which were indicated for street purposes were not intelligently proportioned. (*Better:* The principal reason for poor traffic flow is that the streets were not intelligently laid out.)

> An easy example for explanation purposes would be a shunt-type motor. (*Better:* A shunt-wound motor is a good example.)

In both of the above sentences the word "purposes" is used unnecessarily. In the following sentence the word "nature" is ineptly used:

> The soldering proved to be of an unsatisfactory nature. (*Better:* The soldering proved to be unsatisfactory.)

Finally, here is a sentence in which "position" is at fault:

> With this work now completed, the plant is in a position to proceed with work on the new product.

What revision would you make of this sentence?

Another common source of trouble is the use of adverbs or adjectives in a way that may look fine at first but actually means little or nothing. Words often used in this way are "comparative" or "comparatively," "relative" or "relatively," "undue" or "unduly," "considerable" or "considerably," "definite" or "definitely," and the like. These are all good words when they are used with a concrete reference. But consider the following examples:

> This newly developed machine proved to be comparatively efficient. (This sentence is not meaningful unless we know the efficiency of the machines with which comparison is made.)
>
> Water-flooding effected a substantial increase in production. (This means little without specific amounts.)
>
> The voltage regulator must definitely be checked at periodic intervals. (*Better:* The voltage regulator must be checked at periodic intervals. *Or:* It is important that the voltage regulator be checked at periodic intervals.)

But what is a periodic interval? The time should be stated.

A last illustration follows:

> Research personnel have made appreciable progress in solving this problem. (*Translation:* We haven't found out anything yet, but we have several ideas we're working on.)

A third source of unnecessary words is the use of pointlessly elaborate prepositions and connectives. The sentences below illustrate this problem:

> Greater success has been enjoyed this year than last *in the case of* [by] the engineering department.
>
> This problem is *in the nature of* [like] one encountered years ago.
>
> Our reports must be made briefer *with a view to* ["to" is enough] ensure more successful research-production cooperation.
>
> This recorder has been installed *for the purpose of providing* [to provide] a constant check of volume changes.

Finally, many phrases and clauses used in introducing the main idea of a sentence are unnecessary, and they are often pompous-sounding and stilted as well. Study these examples:

> It is perhaps well worth noting that the results of this study show that plant efficiency is low. [If the main idea the author wants to communicate is that "plant efficiency is low," the elaborate introductory clause is a waste of words. The clause can be justified only if the writer wants to emphasize the idea that "it is worth noting" that plant efficiency is low. "Perhaps" surely serves no useful purpose in either case.]

> It will be observed that test specimen A is superior to test specimen B. [If the author wanted to say simply that "test specimen A is superior to test specimen B" he should have done so without the introductory clause. If he really wanted to say that the superiority of A to B will be *observed*, then his sentence was all right.]

There is no inherent fault in the introductory clauses used above, or in others like them (such as "it will be noted," and "consideration should be given to"); but fault does lie in saying more than is meant and in using a great many words to say what could be said more emphatically and clearly with a few.

Words are used unnecessarily in many more than the four ways we have pointed out, but the problem of avoiding unnecessary words is always to be solved in basically the same way: by thinking about what each of the words in a sentence is contributing to the meaning.

USING SIMPLE, FAMILIAR, CONCRETE WORDS. Probably nobody would deny the wisdom of avoiding unnecessary words, but young engineers are often reluctant to admit that simple and familiar words should be chosen wherever possible in preference to "big" words. In fact, they may resent such a practice as denying them the free use of the technical vocabulary they have been at such pains to acquire. Furthermore, they may feel that substituting simple words for technical terms will inevitably result in a loss of precision of meaning.

It is interesting to note what experienced engineers have to say about this problem. Thomas O. Richards and Ralph A. Richardson, both of General Motors Research Laboratories, say in connection with reports written in their organization that

> the most important factor in technical writing is to keep the vocabulary simple enough so that it can be understood by a great number of people. Big, unusual and technical words must be used sparingly. . . . *We have never had a report submitted by an engineer in our organization in which the explanations and terms were too simple.* [Italics ours.] We avoid highly technical words and phrases and try to make the work understandable, because we know that even the best engineer is not an expert in all lines. . . . Most reports err in being too technical and too formal.*

These engineers are not talking about writing for people without any technical background, someone like a stockholder or a director, but about writing for other technical personnel.

A large company of builders and contractors declares that one of

* Thomas O. Richards and Ralph A. Richardson, *Technical Writing* (Detroit, Mich., 1941), p. 4.

the essential qualities of a good report is that it be clear, concise, and convenient, and adds that "the use of technical words should be limited as far as possible to those with which the prospective readers are familiar." The Tennessee Valley Authority manual on engineering reports has as one of the criteria in its report appraisal chart the question, "Is the language adapted to the vocabulary of the reader?" E. W. Allen of the United States Agricultural Research Administration, in a pamphlet containing suggestions to scientists on the writing of reports, stated:

> . . . it is necessary to understand and keep in mind the point of view of those it is desired to reach . . . it is not enough to use language that *may* be understood—it is necessary to use language that can not be misunderstood. . . . The style of the technical paper should be simple, straightforward, and dignified.*

The list below provides a few examples of the problem these engineers were talking about. Most of the terms in the left-hand column are perfectly good words, and they are the best words in certain contexts. But if you mean "parts" why say "components"? Or if you mean what may be written as either "name" or "appellation," why not take the simpler word? Unless you have a good reason don't substitute

initiate	for	begin
disutility	for	uselessness
compensation	for	pay
conflagration	for	fire
veracious	for	true
activate	for	start
ramification	for	branch
verbose	for	wordy

H. W. Fowler writes sensibly and wittily of this problem in *A Dictionary of Modern English Usage*, in such articles as "Love of the Long Word" and "Working and Stylish Words."

On the other hand, don't ever sacrifice precision for simplicity. There are some ideas that can't be expressed in simple language, and there's no use trying. Nor should you allow an interest in simple language to lure you into using shoptalk or technical slang in writing. Terms like "pot" for potentiometer, "mike" for micrometer or microphone or microscope, and "megs" for megacycles are justifiable in conversation among co-workers because they are convenient and often colorful, but they have no place in formal reports.

* E. W. Allen, *The Publication of Research* (Washington: U.S. Agricultural Research Administration, 1945), p. 4.

Sentence Structure and Length

Good technical writing calls for a natural word order, simple sentence structure, and fairly short sentences.

The normal, natural order of elements in English sentences is (1) subject, (2) verb, and (3) object or complement. Each of these elements may be modified or qualified by adjectives or adverbs. The normal position of adjectives is in front of the term they modify. Adverbs usually appear before the verb, but often after. This order of parts should generally be followed in your sentences, for the sake of clarity and ease of reading. Furthermore, subject and verb should usually be close together. Naturally, departure from these patterns is occasionally desirable to avoid monotony.

The following sentences illustrate some typical word orders:

1. *Natural Order:*

The machine was designed for high-speed work.

2. *Natural Order with Modifying Words and Phrases:*

This 90-ton, high-speed machine was efficiently designed to provide the motive power for a number of auxiliary devices.

3. *Inverted Order:*

Remarkable was the performance of this machine.

4. *Periodic Order:*

When these tests have been completed and the data have been analyzed there will be a staff meeting.

The order of sentences (1) and (2) is usually to be preferred to that of the other two. In both sentences (3) and (4) the principal subject is not clear until near the end of the sentence. Periodic and inverted sentences may certainly be used occasionally, but most of your sentences should be of the natural order.

So far we have been concerned with the effect of word order on the readability of sentences. An intimately related factor is the type of sentence structure employed. In general, simple sentences should outnumber the other kinds of structure: complex, compound, and complex-compound. You will recall from your study of composition that a simple sentence is one containing only one clause; and that a clause is a group of words containing a subject and a predicate. Examples (1), (2), and (3) above are simple sentences. A complex sentence contains an independent clause plus one or more dependent clauses. A compound sentence contains two or more independent clauses. A complex-compound sentence contains two independent and at least one dependent clause.

1. *Complex:*
When all other preparations are made, the final step may be taken. (The introductory clause here functions as an adverb, and is dependent upon the main clause for its full meaning.)

2. *Compound:*
The first stage of this process can be completed under the careful supervision of the shop personnel, but the second stage must be directed by trained engineers. (The compound sentence consists of two statements linked by a conjunction.)

3. *Complex-Compound:*
If this process is to succeed, the first stage can be completed under the careful supervision of the shop personnel, but the second stage must be directed by trained engineers. (Here a qualifying dependent clause is added to the first main clause. Additional qualifying phrases and clauses could of course be added, further complicating the sentence.)

Reading is slowed up by too large a proportion of complex and compound-complex sentences. What is too large a proportion? We wish we could answer that question with a precise figure, but we can't. The writer must have a sense of proportion—and we do intend that word to mean two things: a percentage, and a balance or harmony.

It is quite as possible to go to extremes in the use of short, simple sentences as in the use of complex sentences. If you go too far in the use of simple sentences you may find yourself writing something like this:

> He did not do well with the company at first. Later he managed to succeed very well. Finally he became president of the company.

This is bad writing because there is no use of subordination in it. All the ideas are given the same weight. Linking the three sentences together with simple conjunctions—"but later," "and finally"—would eliminate the unpleasant choppy effect, but what is really needed is subordination of one idea, something like that in the following complex sentence:

> Although he did not do well at first he later managed to succeed very well, finally becoming president of the company.

The word "although" subordinates the first clause. Such a word is called a subordinating conjunction. Some other words that will serve this function are after, because, before, since, in order that, unless, when, where, while, why.

In general, then, the best policy is to make most of your sentences simple in structure and natural in order, but to vary the pat-

tern enough to avoid unpleasant monotony and to provide proper emphasis.

You should also be careful about sentence length. Research has shown that there is a direct correlation between difficulty of reading and sentence length, plus the number of syllables per word. Probably the average length should not be over 20 words. Of course this does not mean that no sentence should be more than 20 words. Nor is it necessary to avoid all words of more than three syllables. A good book to consult on this subject is *The Art of Readable Writing*, by Rudolf Flesch.

Paragraph Structure and Length

A paragraph typically begins with a sentence (the topic sentence) which contains the gist of the idea to be developed. The other sentences of the paragraph develop, support, and clarify this central idea. But, as a matter of fact, you have probably observed that this topic sentence may appear anywhere within the paragraph. It may appear in the middle, or it may appear last, as a summary or generalization based on material already presented. Sometimes it doesn't appear at all, in so many words, but is implied. The requirements of technical style being what they are, we want to urge that you follow the tried practice of placing the topic statement first in the paragraph, or, at the very latest, just after whatever transitional sentences appear. The technical writer doesn't want his reader to be in suspense as to what he proposes to talk about.

Compare the following two versions of a paragraph from a Shell Oil Company manual. Version B is the original; version A is our revision, for the purpose of illustration.

Version A:

> These instructions are not designed to cope with exposure environment where highly corrosive vapors are encountered although the paints recommended do have substantially good corrosion-resistant properties for normal plant tank farm conditions. Where such environments are encountered, special coatings may be required, such as vinyls, chlorinated rubber, Epon resin vehicle materials, or standard and other special paint systems applied to sprayed zinc undercoatings. In these cases proprietary brands may be used until open formulations are available. Experience in the field and the use of exposure test panels, pH indicators and other methods will determine whether it will pay to apply the more expensive corrosion-resistant coatings. Special corrosion problems should be referred to the Atmospheric Corrosion Committee for investigation. On the other hand, the instructions, specifications and formulations contained in this manual are designed to cope adequately with

exposure environments existing in the general run of tank farms where hydrocarbons and the less corrosive chemicals are stored.

Version B:

> The instructions, specifications and formulations contained in this manual are designed to cope adequately with exposure environments existing in the general run of tank farms where hydrocarbons and the less corrosive chemicals are stored. They are not designed to cope with exposure environment where. . . . [as above to last sentence].*

The main idea (the topic sentence) in version B is stated at the beginning so that the reader will know without delay just what the object of the discussion is. It is true that the reader needs to know what will not be covered, but it is more important for him to know what will be covered by the discussion. In A he does not find this out until the very end of the paragraph. Paragraph B is the better of the two.

Two considerations govern paragraph length: unity of thought, and eye relief for the reader. Since the paragraph is defined as the compositional unit for the development of a single thought, it may seem to you that length should be governed entirely by requirements of the development of the thought. And in theory, that's right. A simple, obvious idea, for example, might not take much development —perhaps no more than two or three sentences; a complex and highly important idea might, according to this line of reasoning, require a large number of sentences, perhaps covering several pages.

Long paragraphs, however, do not permit easy reading. If there is no break in an entire page, or more than a page, the reader's attention flags and he finds it difficult to keep the central idea in mind. Since long, unbroken sections of print repel most readers, the writer should devise his paragraphs so that such sections will not occur.

Breaking up discussion so that the reader's eye is given some relief does not demand that the writer violate basic principles regarding the unit of paragraph development. But neither does it mean that he should simply indent at will. The writer has a good deal of freedom in deciding what shall constitute a unit of his thought. An idea containing several parts or aspects may be broken up, with the sentence which originally had stood as a topic sentence for a long paragraph serving as an introductory statement to a series of paragraphs. Let's consider a hypothetical case. Suppose a writer had written:

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* From *Protective Coating Manual*, p. 2. Reprinted by permission of the Shell Oil Company.

> For a brief explanation of the meaning of the term "skip distance" in radio communications, we must first turn our attention to the phenomena of the ground wave, the ionosphere, and the sky wave.

Suppose, further, that this sentence stood as his topic sentence and that he proceeded to develop a description of the three phenomena, all in the same paragraph. Obviously the paragraph would run quite long, too long for comfortable reading. His solution would be simple. Instead of one long paragraph, he could write three shorter ones, one on each phenomenon. The original topic sentence could serve as an introductory, transitional paragraph, perhaps with the addition of another sentence something like this: "Each of these phenomena will now be described in detail." In other words, the writer can arrange his organization so that the material can be divided into conveniently small units.

When you desire an especially forceful effect, try using one or more very short paragraphs.

To sum up, remember that all sentences in a paragraph must be concerned with the same topic but also remember that paragraphs should not be permitted to get too long. Try to have one or more breaks on every page of your report.

Summary

Technical writing style is distinguished by a calm, restrained tone, by the absence of any attempt to arouse emotion, by the use of specialized terminology, and by an accepted convention of the use of abbreviations and symbols. Most organizations expect reports to be written in the passive voice, but there are two other possibilities: the "editorial we," and the third-person active. It is highly desirable to develop a habit of looking critically at sentences to make sure they truly express the ideas they were intended to express. Words and phrases must be used with precision. Clarity and ease of reading are enhanced by the use of moderately short sentences and paragraphs. The organization of both sentences and paragraphs should usually be natural, with main ideas appearing near the beginning.

PART TWO

Common Faults of Usage

Before going on to discuss the accepted standards for the mechanics of style (abbreviations, numbers, and so on) we shall point out some common errors in technical writing, and make some sug-

gestions for eliminating them. Rather than review all the rules of grammatical usage, we shall simply discuss those errors of usage which occur with great frequency and which give particular trouble to report writers.*

Special Subject-Verb Relationships. You do not need to be told that the subject of a sentence must agree with the verb in number, i.e., that a singular subject demands a singular verb, a plural subject a plural verb. Seeing to it that they do agree is another matter, however. At any rate, two constructions give many inexperienced writers a great deal of trouble: (1) sentences in which the subject is essentially plural but technically (or grammatically) singular, and (2) sentences with relative clauses.

Study the following sentences. The first seven illustrate (1) above, the last two illustrate (2).

1. *Either* of these power supplies *is* satisfactory. (Since "either" is singular, "is" must be used instead of "are" but many writers let the prepositional phrase with the plural object "supplies" mislead them into choosing "are." "Neither," "one," "everyone," "each," contain similar pitfalls.)

2. A *series* of tests *was run* to determine the strength of these materials. (Here "series" takes a singular verb.)

3. The *majority* of these devices *was* rejected.

4. *Everyone* in the organization *makes* a weekly progress report. (Several people are obviously involved, but "everyone" takes a singular verb.)

5. This *group* of elements *is characterized* by similar properties. ("Group" is singular.)

6. The *carburetor* together with other components of the engine *is* easy to service. (Although this compound subject is obviously plural, formal English calls for a singular verb. Expressions like "with," "together with," and "as well as" are often used to link the first part of a compound subject to the last; if the first is singular, use a singular verb in formal writing. In informal, colloquial usage, the plural is acceptable.)

7. Either the mainspring or the *connections are* giving trouble. (With an "either-or" or "neither-nor" construction, the verb will agree with that part of the subject nearest it.)

8. One of the main *errors which were* involved . . . (The relative pronoun "which" refers to "errors" and hence the verb is plural.)

9. This is one of those *parts which are* always giving trouble. (Correct because "which" refers to "parts" which is plural.)

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* The discussion that follows is based in part on a survey of errors committed by students of chemical engineering at the University of Texas.

Remember that the verb following a relative pronoun must agree with the noun to which the pronoun refers.

VAGUE USE OF "THIS," "WHICH," AND "IT." Since a pronoun conveys no information in itself but is meaningful only in reference to the word or phrase for which it stands, the reference should be unmistakably clear. "Ambiguity" is the fault when the reference is not clear. Notice the lack of clearly defined reference in the following sentences:

> Panels should be exposed at more than one test station on exterior racks and regular inspections should be made. This will require trained personnel. (Does "this" refer to exposing the panels, making inspection, or both? As the sentence stands it is impossible to be sure. If inspections, the second sentence should begin "Inspections will . . . .")

> The appended formulation for aluminum is designed to have fairly satisfactory self-cleaning properties which makes it suitable for decorative purposes but not as good as white. (Here "which" probably refers to the fact that the formulation has self-cleaning properties. If reference is to "properties" the verb "makes" should be "make" to agree in number —see above. A better version of the sentence is "The self-cleaning properties of the appended formulation for aluminum make it suitable . . . ."

> The remaining two tubes of the circuit are V101a and V101b. It controls . . . . (This use of "it" refers to V101a or V101b. The solution is obvious: V101a (or V101b) should be substituted for "It.")

Taken out of context as the above sentences are, their faults may appear so obvious that you would be inclined to say that any careful writer would avoid them. Yet errors like these are made over and over again in engineering reports.

DANGLING MODIFIERS. A dangling modifier is one which has nothing to modify logically or grammatically, or one which seems to modify a word it cannot possibly modify. In technical writing, dangling participial and dangling infinitive phrases are very common, mainly because of the difficulties involved in describing action in the passive voice. Remember that any phrase expressing action must be related to a specific word that names the actor. Let's examine a few typical sentences.

1. *Dangling Participial Modifiers:*

> After connecting this lead to pin 1 of the second tube, the other lead is connected to pin 2. (Who connects the lead to pin 1? It can't very well be "the other lead" that does so! Two correct possibilities suggest themselves. "After this lead has been connected to pin 1 of the second tube, the other lead is connected to pin 2." *Or:* "After connecting this lead to

pin 1 of the second tube, the technician connects the other lead to pin 2." In this second sentence, the introductory phrase logically modifies the subject of the main clause, "The technician." He is the one who did the connecting. In the first sentence, the introductory, active participial has been changed to passive to agree with the voice of the main clause.)

When starting the motor from rest in the forward direction, the main coil PEM is de-energized and the IR drop across PFN produces a flux to oppose the residual magnetism left by PFN. (The introductory phrase, "When starting the motor . . ." leads the reader to expect that the subject of the main clause will name the starter, but he is disappointed. "Coil" is the subject of the main clause and it did not start the motor from rest. "When the motor is started from rest . . ." would solve the difficulty.)

In selecting the rectifier, current limiting resistors, and holdout coil, this must be considered. (The participial phrase may be kept if the main clause is made to read "The engineer must consider this." Otherwise the introductory phrase must be changed.)

2. *Dangling Infinitive Modifiers:*

To start the motor, the starter button must be depressed. ("To start the motor, the driver must depress the starter button" keeps the infinitive phrase from dangling because we now have "the driver" to relate the action to.)

To achieve a mix of the proper consistency, more sand must be added. (Main clause needs a subject like "you" or "the worker.")

Ordinarily, dangling modifiers occasion no real obstacle to understanding for the reader, but now and then, as in the following sentences, they cause him amusement.

After drying for three days under hot sun, workers again spray the concrete with water.

After taking in a constant flow of oil for two days, the supervising engineer will note that the tanks are nearly full.

Although neither confusion nor amusement usually results from dangling modifiers, there is no guaranteeing that they won't. The problem deserves your attention.

Lack of Parallel Structure. Parallelism means the use of similar grammatical structure in writing clauses, phrases, or words expressing ideas or facts which are roughly equal in value. A failure to maintain parallelism results in what is called a "shifted construction." Parallelism is made clearer by these illustrations:

1. *Parallelism of Word Form:*

His report was both *accurate* and *readable*. ("Both" introduces two adjectives which describe the report. The parallelism would be lost if the sentence read, "His report was both accurate and it was easy to read.")

The process is completed by sanding, varnishing, and buffing the finish. (*Not:* "The process is completed by sanding, varnishing, and the buffing of the finish." The last item in the series is not parallel with the first two.)

2. *Parallelism of Phrases:*

Preparing the soldering iron, making the joint, and applying the solder constitute the main steps in soldering an electrical connection. (All the initial terms of the phrases are participials to make the construction parallel. A failure of parallelism would give us something like this: "Preparation of the soldering iron, making the joint, and application of the solder . . . .")

3. *Parallelism of Clauses:*

That this machine is superior to the others and that this superiority has been demonstrated by adequate tests have been made clear in the report. (The introductory "that" of both of the clauses helps make the parallelism clear. A violation of this parallelism would exist if we had: "That this machine is superior to the others and this superiority is demonstrated by adequate tests have been made clear in the report.")

A shifted construction is sometimes caused by a change in point of view, as shown by the following examples:

A change from a personal style to an impersonal, objective one: "First I shall consider the points in favor of this program and second the disadvantages to the program will be considered."

A change from the imperative mood to the indicative: "First, the wires should be spliced. Next, take the soldering iron . . ."

A change from the active to passive voice in the same sentence: "The workman wraps insulation around the joint before the repaired joint is replaced by him in the circuit."

Mechanics of Style

What we mean by the term "mechanics of style" is the use of abbreviations, numbers, symbols, word forms (particularly compounds), capitals, italics, and punctuation. Our purpose here is to provide some dependable rules for you to follow in handling these problems of usage. Usage in the mechanics of style has by no means become standardized over the country, and we can lay no claim to final authority in setting down standards to follow. You may dis-

cover later on, for instance, that some of the suggestions we make are not followed in the organization you work for. If so, you should certainly follow the rules of your own group. We might add this, however: What we set down is based on reputable, authoritative practice throughout the country. If rules for style mechanics are not provided in the organization you work for, follow these and you may feel confident that you are in line with acceptable usage.

ABBREVIATIONS. Abbreviations should be used only when they are certain to be understood by the reader. Otherwise the term should be spelled out. Certain terms, of course, are commonly abbreviated everywhere—Dr., Mr., B.C., and the like.

The best authority for the use of abbreviations of scientific and engineering terms is the list approved and published by the American Standards Association (March, 1941); although not uniformly followed everywhere (as you will note in the reports quoted later), this standard has the approval of most engineering societies. The following rules are in agreement with this publication (and a list of the more common, approved abbreviations may be found in Appendix D):

1. In general, use abbreviations sparingly in the text of reports—never when there is a chance the reader will not be familiar with them.

2. Abbreviations for units of measurement may be used but only when preceded by an exact number. Thus, write "several inches," but "12 in." Do not use an abbreviation of a term which is the subject of discussion; thus do not write, "The bp was quickly reached." Prefer "The boiling point was quickly reached." Abbreviations may be justified in tables, diagrams, maps, and drawings where space needs to be saved.

3. Spell out short words (four letters or less) like ton, mile, day.

4. Do not use periods after abbreviations unless the omission would cause confusion, as where the abbreviation is identical to a word. Thus write "in." rather than "in" because the latter might be mistaken for the preposition. Some exceptions are "cot" for cotangent, "sin" for sine, "log" for logarithm. These abbreviations could scarcely be confused with the words.

5. Do not add an "s" to form the plural of an abbreviation. The number preceding an abbreviation of a unit of measurement sufficiently marks the expression as plural. Thus write "128 bbl" rather than "128 bbls." Exceptions are Nos. for "Numbers," Figs. for "Figures," Vols. for "Volumes." In footnotes, the plural of "pages" is given as "pp."

6. Write abbreviations in lower-case letters rather than capitals unless the term abbreviated is a proper noun. Thus write "hp" rather than "H.P." or "HP" for horsepower, but write Btu for British thermal unit.

Exceptions are terms used in illustrations or bibliographical forms, as shown above.

7. Abbreviate titles only when they precede a proper name which is prefaced by initials or given names. Write "Professor Jones" rather than "Prof. Jones." "Prof. J. K. Jones" is acceptable.

8. Do not space between the letters of an alphabetical designation of an organization. Write "ASA" for American Standards Association, "ASEE" for American Society for Engineering Education, "ASME" for American Society of Mechanical Engineers, and so forth.

9. Use abbreviations which are more readily recognized than the spelled-out form. Thus, in reports, "FM" is as acceptable as "frequency modulation."

10. In reports where a term is used repeatedly, use the accepted abbreviation but give a spelled-out parenthetical explanation upon first using it. Thus you could write ". . . 1200 cps (cycles per second) . . ." and thereafter use "cps."

SYMBOLS. As a general rule, symbols should be avoided in text. You may find that custom permits the use of certain symbols in particular organizations, however, and our recommendation is that you observe closely what local practice is and follow it in writing reports for the organization for which you work. But while symbols are generally to be avoided in text, they are justifiable in tables, diagrams, and the like because of the need to conserve space. You are doubtless familiar with most of the commonly accepted symbols, such as ″ for inches ′ for feet, x for by, # for number, / for per, & for and. A few symbols, like % for per cent and ° for degree are pretty commonly used in text. Most readers are as familiar with the symbol as with the spelled-out term.

NUMBERS. The following rules represent commonly accepted practice in the use of figures:

1. Use figures for exact numbers for ten and above and spell out numbers below ten. Where several numbers, some above and some below ten, appear in the same passage, use figures exclusively. Thus write:

10 days
eight resistors
five tubes
27 motors
11 condensers, 8 tubes, and 27 feet of wire

2. Use figures in giving a number of technical units, as with units of measurement, whether below or above ten:

8 kcps
2500 hp
28,000 Btu
3 bbl

3. Spell out either the shorter or the first number in writing compound number adjectives:

thirty 12-in. bolts
8 six-cylinder engines

4. To avoid possible confusion in reading, place a zero before the decimal point in writing numbers with no integer:

0.789
0.0002

Do not place zeros to the right of the last figure greater than zero unless you wish to show that accuracy exists to a certain decimal; thus you might write 6.7000 if accuracy to the fourth decimal exists.

5. Spell out fractions standing alone, as "three fourths of the staff members." But with technical units, use figures:

3–1/2 gpm
5–1/4 sec

(Note the form used; 3½ and 5¼ are not desirable in typed copy because the fractions tend to blur, especially on carbon copies, and because typewriters do not have all fractions.)

6. Omit the comma in four-digit numbers (practice is not uniform on this point but the trend is toward omission):

7865
98,663

7. Follow conventional usage in writing street addresses, dates, and sums of money:

4516 Spring Lane
3600 Fifty-fourth Street
March 11, 1951
$8,000,000 or 8 million dollars or $8 million

8. Do not use numerals for round-number estimates or approximations or at the beginning of a sentence:

about thirty times a minute
nearly five hundred arrived
Twenty-seven seconds elapsed (*Not:* "27 seconds elapsed").

9. Do not use two numerals in succession where confusion may occur:

On August 12, eleven transformers burned out.

10. Use numerals for the numbers of pages, figures, diagrams, units, and the like:

Fig. 8, stage 4, page 6, unit No. 5, Circuit Diagram 14.

Hyphenation of Compounds. Usage remains rather uncertain in the handling of hyphenation—as illustrated in the reports that are quoted later—but the following practices are generally approved:

1. Hyphenate compound adjectives which precede the term they modify:

alternating-current motor
ball-and-socket joint
4-cycle engine
two-ton trucks

2. In general, hyphenate compound verbs, such as "heat-treat," "direct-connect."

3. Do not hyphenate adverb-adjective combinations, such as "newly installed," "readily seen."

4. In general, do not hyphenate compound nouns (such as boiling point, building site, bevel gear, circuit breaker) except those composed of distinct engineering units of measurement (such as foot-candle, gram-calorie, volt-ampere, kilogram-meter). Many compounds are, of course, written as one word (such as setscrew, flywheel, overflow).

5. In specific cases, try to observe and follow the practice of careful writers.

Capitalization. So far as general usage is concerned, technical writing style calls for no departure from the conventional rules for the use of capital letters. You have learned to capitalize proper names, names of cities and states, official titles of organizations, and so on. Any reputable dictionary or handbook of English can serve as a guide to conventional usage (and most of them contain a prefatory section stating the "rules"). We should like to call attention to two practices common to reports:

1. Capitalize all important words in titles, division headings, side headings, and captions. By "important" is meant all words except articles, prepositions, and conjunctions.

2. Capitalize Figure, Table, Volume, Number as part of titles. Thus reference would be made to Figure 4, Table 2.

When in doubt, do not capitalize.

Punctuation. The sole purpose of punctuation is, of

course, to clarify thought, to make reading easy. Punctuation which does not contribute to this purpose should be avoided. Most of your difficulties with punctuation are likely to arise in the use of the comma, the semicolon, and the colon. For information on other punctuation marks, see any good handbook of grammar.

The principal uses of the comma are as follows:

1. Between independent clauses connected by a coordinating conjunction (and, but, for, or, nor, yet). But if commas are used within any of the independent clauses constituting a sentence (in accord with one or more of the rules below) a semicolon must be used between the clauses. Study these two sentences:

> The fixed coil is permanently connected across the line, and the movable coil is connected across the motor armature.
>
> The fixed coil, providing a unidirectional magnetic field in which the moving coil acts, is permanently connected across the line; and the movable coil, which operates to close the indicated contact, is connected across the motor armature.

2. After introductory clauses or phrases preceding the main clause of the sentence:

> After the workers had completed the first part of the job, they immediately began the second.
>
> Jumping on the instant of the explosion, he avoided injury.

3. Between items of a series:

> The power supplies, the amplifiers, and the resistors are to be considered now.
>
> The engine was efficient, cheap, and light in weight.

4. Around parenthetical, interrupting expressions, appositives, and nonrestrictive modifiers:

> This plan, unless completely misjudged, will bring great success.
>
> This circuit breaker must, obviously, be kept in repair.
>
> He approved, for the most part, of our research plans.
>
> Mr. Jackson, chief technical adviser, returned yesterday.
>
> The chief project engineer, who used to work on the west coast, is responsible for the new procedure.

But not around restrictive modifiers:

> The generator which was tested yesterday is the one needed in this installation. (Restrictive modifiers, like "which was tested yesterday" cannot be left out without destroying the important idea.)

The semicolon is a stronger mark of separation than the comma, almost as strong as the period. It is chiefly used between independent clauses not connected with one of the coordinating conjunctions and, as suggested by item (1) in the foregoing discussion of the comma, between clauses connected with a coordinating conjunction but which are quite long, or unrelated, or contain commas. Study these sentences in which semicolons appear:

> The first of these devices failed after one year's use; the second has lasted five years.

> One of these instruments has never had to be replaced; however, it is showing signs of wear.

> Even after months of study, they failed to solve the problem; but, in some ways at least, they made a great deal of progress.

The colon means that something is to follow, usually something explanatory, as shown in the following examples:

> A few tools were available: a lathe, a power hack saw, and a drill press.

> Operation was becoming uneconomical: both labor and fuel costs were more than had been anticipated.

> There are three steps in the process: cutting, grinding, and polishing.

The colon is also used in certain special ways, as in the salutation in a business letter (Dear Sir:), in separating hours and minutes in a statement of time (10:30 A.M.), or in separating volume and pages in a bibliographical entry (17:43–50).

One special comment on punctuation in reports: do not place any mark of punctuation after main or side headings (those which are centered on the page and those which stand on a line alone). If, however, text continues on the same line as a heading, as it does with the heading "Punctuation" (page 38), a period should be used. Some organizations prefer the colon.

4

Outlines and Abstracts

Introduction

Outlines and abstracts are very much alike in one respect—both are highly condensed statements of, or descriptions of, the content of a piece of writing. It is for this reason that they are taken up together in this chapter. We shall not make any particular effort to point out their similarities, except as occasion may require, but many similarities will become evident.

Abstracts, unlike outlines, are written solely for the convenience of the reader. Their purpose is to enable the reader to learn the chief points in the content of a report without having to read the report itself.

Outlines, on the other hand, serve two purposes: (1) they provide a means by which you can analyze the organization of somebody else's writing, and (2) they serve as a guide for the writing you do yourself. Our interest will lie almost entirely in the second purpose, the outline as guide. If you have never done any outlining, however, it might be wise to write some analytical outlines in order to learn the basic principles. In that way you can concentrate on the form and

logic of the outline, without at the same time worrying about whether you're developing a good organization.

Why write an outline? Well, why follow a road map? Probably you have driven a car in a strange city for which you had no map, and after having to turn around and retrace your route a few times, and after asking pedestrians for information, you have finally pulled up to your destination. Writing is often like that. The writer runs off first in one direction and then another, while the bewildered reader tries to make sense of his tangled trail. A "road map" would have saved time for both writer and reader.

Of course you do not need a road map to drive from your house to the corner drugstore; nor do you need an outline for a very short report. The longer the road, the more complex the terrain, and the more unfamiliar the country, the more you need a map. And so it is with outlines. The more complex the subject, the more unfamiliar you are with the subject, and the longer the report, the more you need an outline. We shall be primarily concerned with the outline as an aid to the writer, but it might be noted that a table of contents, which is essentially an outline, is an aid to the reader.

We shall discuss, first, outlines; then abstracts; and finally introductory summaries. An introductory summary is a combined introduction and abstract, as will be explained later.

OUTLINES

Kinds of Outlines. There are three kinds of outlines: topic, sentence, and paragraph. A topic outline is an outline in which each entry is a phrase or a single word; no entry is in the form of a complete sentence. Conversely, a sentence outline is an outline in which every entry is a complete sentence. If you will now turn to pages 48 and 51 you will find examples of these two kinds of outline. The third kind, the paragraph outline, is of no use to the technical writer and we shall not discuss it.

The sentence outline has one important advantage over the topic outline, but it also has at least one important disadvantage. The advantage is that in using the sentence form the writer is forced to think out each entry to a much greater degree than in the topical form. Where in a topical form he might say merely, "Materials," in the sentence form it would be necessary to say something like, "The materials required are seasoned white pine, glue, and whatever finish is desired." This greater thoroughness in the sentence outline lessens the possibility of ambiguity and vagueness in the thought. It also means, on the other hand, that the sentence outline is more difficult

and time consuming to write than the topical. The sentence outline is an excellent analytical device to use in studying the organization of a given piece of writing. The topic outline, however, is more practical as a guide to use while writing. It is not a good idea to combine the two forms. There is nothing greatly wrong with such a combination, but it does indicate an inconsistency in the logical process —one part of the subject being developed in detail in sentence form, another being limited to topical development.

THE LOGIC OF OUTLINES. The fundamental principle of outlining is division. The subject to be outlined is divided into major parts (Roman-numerals divisions); these major parts are divided into subparts (capital-letter divisions); these capital-letter divisions are divided into sub-subparts (Arabic-numeral divisions); and so the whole is divided into smaller and smaller units to whatever degree seems desirable.

Since outlining is a method of dividing, it naturally conforms, in a certain degree, to the principles of arithmetic. Let X equal the entire subject to be divided, or outlined. Then $X = I + II + III + \ldots n$. In turn, $I = A + B + C + \ldots n$, and $A = 1 + 2 + 3 + \ldots n$. And so forth. Please understand that this is more than an analogy. It is a principle which not only can be but should be applied to every outline you write, to test its logical soundness. For instance, we might consider the following simple example from the outline on page 49. This outline is taken from a report on the subject of sanitation in isolated construction camps.

I. ....

A. ....

B. Stopping the spread of these diseases by breaking the cycle of transmission

1. Removing or destroying the breeding places of insects and rodents

2. Killing the adult insects and rodents

This might be rewritten in the following form

Stopping the spread of these diseases by breaking the cycle of transmission = Removing or destroying the breeding places of insects and rodents + Killing the adult insects and rodents.

Therefore:

$$B = 1 + 2.$$

This is all simple and obvious. But it's not unlikely that the first outline you write after reading this chapter will have some sections that will absolutely refuse to "add up." We may as well recognize the fact that good outlines often call for hard thinking. Experience makes many difficult things seem simple, however, and you should by no means feel discouraged if at first you have trouble. The suggestions contained in the next section of this chapter should be helpful.

The subject of the form of outlines deserves some attention. The form most commonly used is the following. The dotted lines represent the text.

```
I. .................................................
   ..........
   A. ..............................................
      ......
      1. ...........................................
         ..........
         a. ........................................
            ..........
            (1) ....................................
                ..........
                (a) ................................
                    ..........
                (b) ................................
            (2) ....................................
         b. ........................................
      2. ...........................................
   B. ..............................................
II. ................................................
```

Observe the following points: (1) Periods are used after symbols, (that is, numbers or letters) except when the symbol is enclosed in parentheses. (2) In an entry which requires more than one line, the second line is started directly beneath the beginning of the first. (3) The symbol of a subdivision (A, 2, etc.) is placed directly beneath the first letter in the entry of the next highest order. (4) Periods are placed at the end of sentence entries but not after topic entries. (5) Lines are usually double-spaced.

There is one other aspect of form which calls for attention. That is the need for parallel grammatical structure in the sentence or

topic entries. This may look like an unimportant matter, but our own opinion is that carelessness in this respect is not infrequently like the tiny fissure on an exposed slope of earth which, if not attended to, may become a badly eroded gully. An explanation of parallelism can be found on page 34.

Some Advice on How to Make an Outline. We are chiefly concerned here with an outline to be used as a guide for writing, and only to a limited degree with analytical outlining. Probably the best way to start making an outline is to make some lists. Sometimes it helps if you just forget the word "outline." First, make a list of all of the things you want to discuss. Then it may be wise to make another list of things that you think the reader should be told.

Next write out a sentence beginning, "The purpose of this report is. . . ." When you have completed this sentence, it is time to look over your lists, picking out the major (Roman numeral) topics, and putting them in proper sequence. Each one should contribute something toward the purpose just stated in your sentence.

Finally, go through the major topics one by one and make a list, at first in random order, of the things that should be discussed in connection with each major topic. After the major topics have been taken care of, go on to the subtopics.

In short, think of the whole problem of outlining as one of making a list of reminders to yourself. Careful attention to principles of logic and of form will make the list easy to use, and will help prevent ambiguity and vagueness in thinking and writing.

ABSTRACTS

An abstract is a short description of, or a condensation of, a piece of writing. It is a timesaving device. Naturally, it is a device that is highly popular with executives. The man whose opinion of your report matters most may read only the abstract of it.

We shall identify the two types of abstracts, note their respective advantages, and then make some remarks on how to write an abstract.

Types of Abstracts. One type of abstract is the descriptive. In it is found information about what topics are taken up in the report itself, but little or nothing about what the report says concerning these topics. This type of abstract is illustrated on page 52. The advantages of a descriptive abstract are that it is easy to write and is usually short; a serious disadvantage is that it contains relatively little information.

The other type of abstract is sometimes called the "informa-

tional" type. In this sort of abstract, which is illustrated on page 52, there is a restatement of the chief points made in the report. Instead of learning merely that such and such topics are taken up in the report, we are told something of what the report has to say about these topics. The advantage of an informational abstract is that it provides much more information than does a descriptive abstract. Of course, it is harder to write, and it may be a little longer than the descriptive type. Except where length is of special importance, however, there can be no question as to the superiority of the informational type.

Then how long should an abstract be? A good rule of thumb is to make it as short as you can, and then cut it by half. Some people say it should be about 5 per cent as long as the report itself.

In concluding these remarks on types of abstracts, we must point out that most abstracts are not exclusively either descriptive or informational, but are a combination of both. This is perfectly all right. As a matter of fact, the first sentence in the descriptive abstract on page 52 is more nearly "informational" than descriptive. Writing an abstract invariably presents a problem in compromising between saying everything you think you ought to, and keeping it as short as you think you ought to. Use of descriptive statements here and there in an informational abstract often helps to solve this problem. Sometimes the term "epitome" is applied to a very short informational abstract in which only the most important facts or ideas are presented, and the term "abstract" is reserved for a longer, more detailed statement. Whatever the terminology you encounter, you have fundamentally two sets of inversely proportional variables to deal with: brevity vs. detail, and description vs. information.

SUGGESTIONS ABOUT WRITING ABSTRACTS. The best suggestion we can make about writing an abstract is to have a well-organized report to start with. Having that, you simply write a brief summary of each one of the major divisions of the report. It is often wise to write the abstract from the outline rather than from the text, except for checks as to facts.

Another suggestion is that you give special attention to sentence structure. Use of subordination particularly helps to produce a short, smooth, highly informative abstract.

In form, the abstract is usually set up as a single paragraph, double-spaced, on a page by itself. It should be written in good English: articles should not be omitted, and no abbreviations should be used which would not be acceptable in the body of the report. Often, a special effort should be made to avoid terminology which might be unfamiliar to an executive, or any other likely reader who is not in-

timately acquainted with the work. With the exception noted in the next section, the abstract should be regarded as a completely independent unit, intelligible without reference to any part of the report proper.

INTRODUCTORY SUMMARIES. Abstracts are sometimes called summaries, so it is easy to guess that an introductory summary is a combination of introduction and abstract. It isn't exactly a combination, however, in the way that H_2 and O make water; it is rather a joining together, as a handle and a blade make a knife. It's still easy to identify both parts.

There are really two kinds of introductory summaries. One is just an ordinary abstract that happened to be put at the top of the first page of the text of a report. The only thing introductory about it is the fact it is the first thing the reader is introduced to. Since this is just a matter of what name you want to call an abstract by, we shall say no more about it.

In the second type of introductory summary special emphasis is given to the introductory portion. The idea back of this is to show clearly at the outset how the project being reported on fits into the whole program of which it is a part. If the report itself is short there may be no further introductory material. In longer reports there is likely to be a formal introduction following the introductory summary. There is always a temptation, however, to let the introductory summary do the whole job, even when a separate formal introduction is definitely needed.

The introductory summary that follows is a fictitious one which the Hercules Powder Company has used as a model for its staff. The Hercules Powder Company calls it a digest. This is as good a term as introductory summary, and happens to be more useful in the procedure followed at Hercules.

Terpene Sulfur Compounds—Preparation*

DIGEST

In previous progress reports under this investigation, terpene sulfides were prepared and tested as flotation reagents with negative results. From theoretical considerations, there was reason to believe that terpene mercaptans would be satisfactory flotation reagents. However, no method of preparing these compounds was known. It was suggested that

* From *The Preparation of Reports* (3d ed.; Wilmington, Del., 1945). pp. 32–33. Quoted by permission of the Hercules Powder Company.

terpene hydrocarbons might add hydrogen sulfide directly to form mercaptans. To test the possibility of this reaction, experiments were carried out, during the period covered by the present report, in which hydrogen sulfide was bubbled through separate samples of pinene and also of Dipolymer at atmospheric pressure and room temperature in the presence of catalysts.

Catalysts employed with pinene were 85% phosphoric acid with and without Darco, 90% phosphoric acid, and 32% sulfuric acid. The best results were obtained with the use of a catalyst consisting of 85% phosphoric acid and a small proportion of Darco. The sulfur content of the product indicated that the apparent yield with such a catalyst was 94%. Without Darco, the yield was 68 and 81% with 85 and 90% phosphoric acid, respectively. With 32% sulfuric acid, the yield was 83%. Dipolymer when tested similarly with 85% phosphoric acid and Darco gave a somewhat lower yield.

Further experiments will be carried out with pinene under other reaction conditions. It is planned to carry out the reaction under superatmospheric pressure. The pure mercaptan will be isolated and tested as a collector in ore flotation.

The first paragraph in the example above is obviously the introductory portion. It gives the reader a clear statement of the general situation. The remainder is an informational abstract.

ILLUSTRATIVE MATERIAL

The following pages contain illustrations of outlines and abstracts. There are four exhibits, all of which are based on a single section, "Insect and Rodent Control,"* of a report entitled *Sanitation Requirements for an Isolated Construction Project,* by Mr. Jerry Garrett. The four exhibits include the following:

1. A topic outline
2. A portion of a sentence outline
3. A descriptive abstract
4. An informational abstract

Topic Outline

I. Introduction
  A. Flies, mosquitoes, and rats as the vehicles of infection for ten widespread diseases
    1. Flies
      a. Mechanical transmission of disease
      b. Intestinal diseases they transmit

* This section is quoted in full in Appendix E.

(1) Typhoid

(2) Paratyphoid

(3) Dysentery

(4) Cholera

(5) Hookworm

2. Mosquitoes

a. Transmission of disease by biting

b. Diseases they transmit

(1) Malaria

(2) Yellow fever

(3) Dengue

3. Rats

a. Transmission of disease through harboring fleas

b. Diseases they transmit

(1) Plague

(2) Typhus

★ B. Stopping the spread of these diseases by breaking the cycle of transmission

1. Removing or destroying the breeding places of insects and rodents

2. Killing the adult insects and rodents

II. Breeding control

A. Introduction

B. Flies

1. Breeding habits

2. Control measures

a. Sewage disposal

b. Removal of manure

(1) Time limit

(2) Storage bins

(3) Compression

c. Destruction of all decaying organic matter

C. Mosquitoes
   1. Differences from flies
      a. Greater difficulty in control of breeding places
      b. Small percentage that carry disease
   2. Disease-transmitting mosquitoes
      a. Female *Aedes aegypti*
         (1) Transmission of yellow fever and dengue
         (2) Breeding in clean water in artificial containers
      b. *Anopheles quadrimaculatus*
         (1) Transmission of malaria in southern U.S.
         (2) Habit of biting at night
         (3) Breeding in natural places
            (a) Preference for stationary water
            (b) Protection afforded by vegetation and floating matter
   3. Control measures
      a. Removal of water
      b. Spreading oil on stationary water

D. Rats
   1. Lack of direct ways to control breeding of rats or their fleas
   2. Prevention of breeding in specific areas
      a. Building rat-resistant houses
      b. Keeping rats from food

III. Adult control

A. Flies
   1. Screens
   2. Traps
   3. Baits
      a. Fish scraps
      b. Overripe bananas
      c. Bran and syrup mixture
   4. DDT

B. Mosquitoes

1. Screens
2. Larvae-eating minnows
3. Poisons
   a. DDT
   b. Pyrethrum

C. Rats

1. Importance in property destruction as well as in disease
2. Poisons
   a. Barium carbonate
   b. Red squill
   c. 1080
   d. Antu
3. Trapping
4. Fumigating

Sentence Outline

I. The fact that flies, mosquitoes, and rats transmit ten diseases makes it important that these insects and rodents be destroyed by preventing them from breeding or by killing adults.

A. Flies, mosquitoes, and rats transmit ten widespread diseases.

1. Flies transmit five intestinal diseases.
   a. Flies are mechanical carriers of diseases.
   b. They transmit typhoid, paratyphoid, dysentery, cholera, and hookworm.
2. Mosquitoes transmit three diseases.
   a. Mosquitoes spread diseases by biting.
   b. They transmit malaria, yellow fever, and dengue.
3. Rats transmit two diseases.
   a. Rats transmit disease through harboring fleas.
   b. They transmit plague and typhus.

B. The spread of the diseases listed above can be stopped by breaking the cycle of transmission.

1. The breeding places of insects and rodents can be removed or destroyed.

2. The adult insects and rodents can be killed.

Descriptive Abstract

Flies, mosquitoes, and rats are vehicles of infection for ten widespread diseases. These diseases can be prevented by removing or destroying the breeding places of these insects and rodents and by killing their adult forms. Proper methods of control are described.

Informational Abstract

Flies, mosquitoes, and rats are vehicles of infection for ten widespread diseases. These diseases can be prevented by removing or destroying the breeding places of these insects and rodents and by killing their adult forms. The breeding of flies is controlled by proper disposal of decaying organic matter, and of mosquitoes by destroying or draining pools, or spraying them with oil. For rats, only the indirect methods of rat-resistant houses and protected food supplies are valuable. Control of adult forms of both insects and rodents requires use of poisons. Screens are used for insects. Minnows can be planted to eat mosquito larvae.

★

section two

Special Techniques of Technical Writing

The five chapters that follow are devoted to a discussion of five writing techniques that are of especial importance to scientists and engineers. These techniques are definition, description of a mechanical device, description of a process, classification, and interpretation.

As was pointed out in Chapter 1, these techniques must not be thought of as types of reports. Normally, several of them would be involved in the writing of a single report. In contrast, it would be unusual to find an entire report, even a short one, involving only one of these techniques. Furthermore, two or more techniques are often complexly interwoven in a report as the writer describes, for instance, the design, construction, and operation of a mechanical device. Even where this intermingling of techniques occurs, however, there is no alteration in the basic principles of their use. And the basic principles can of course be studied most effectively by taking one technique at a time.

Our treatment of these techniques will be practical rather than theoretical, particularly in the chapters on definition and classification.

5

Definition

In this chapter on definition we have three specific objectives: (1) to set down some facts intended to clarify the problem of what should be defined in technical writing; (2) to suggest effective methods for defining what needs to be defined; and (3) to point out where definitions can be most effectively placed in reports.

What to Define

Before we can fairly tackle the problem of *how* to define, we must first think about *what* should be defined. It is not possible, of course, to set up an absolute list of terms and ideas which would require definition, not even for a specific body of readers, but it is possible and highly desirable to clarify the point of view from which the problem of definition should be attacked.

First of all, we should call to mind a rather obvious but extremely significant fact about the nature of language: words are labels or symbols for things and ideas. The semanticists—those who study the science of meaning in language—speak of the thing for which a word stands as its "referent." For instance, five letters of the alphabet, l-e-m-o-n, are used as a language symbol for a fruit with which we are

all familiar. In a sense, it is unimportant that these letters happen to be used, for the lemon would be what it is no matter what combination of letters was used to name it. This fact, however obvious, is an important one to keep in mind, for it often happens that a writer and reader are not in perfect agreement as to the referent for certain words. That is, the same word, or symbol, may call to the reader's mind a different referent from the one the writer had in mind, and thus communication may not be achieved. Or, more importantly for our purposes, a word used by the writer may not call to the reader's mind any referent at all. Thus a reader who is actually familiar with banana oil from having used it may not have it called to mind by the technical term "amyl acetate" because the latter term is unfamiliar to him.

This matter of the relationships of words to the ideas and things for which they stand can become very complex, but without going into the problem of semantics any further we can say that the words you use as a writer will, so far as your reader is concerned, fall into the following categories:

1. Familiar words for familiar things
2. Familiar words for unfamiliar things
3. Unfamiliar words for familiar things
4. Unfamiliar words for unfamiliar things

Each of these categories deserves some attention.

FAMILIAR WORDS FOR FAMILIAR THINGS. The only observation that needs to be made about the first category is that familiar words for familiar things are fine; they should be used whenever possible. To the extent that they can be used, definition is unnecessary. This might be dismissed as superfluous advice were it not for the fact that a great many writers often appear to seek unfamiliar words in preference to everyday, simple terms. There is, as a matter of fact, a tendency for some people to be impressed by obscure language, by big words. Thus we find "amelioration" when "improvement" would do as well, "excoriate" for "denounce," "implement" for "carry out" or "fulfill," and the like. It scarcely needs to be pointed out that a "poor appetite" is not really changed—made more or less severe—by being called "anorexia"; yet there are those who would much prefer the latter term. Nothing is ever gained by using, just for their impressiveness, what you have probably heard called "two-dollar" words, and often much is lost.

FAMILIAR WORDS FOR UNFAMILIAR THINGS. The words of this second category present a rather special problem to the technical

writer and one that he needs to be especially alert to. These are the everyday, simple words which have special meanings in science and technology.* Most of them may be classed as "shoptalk," or language which is characteristic of a given occupation. Because they are a part (often a very colorful part) of the technical man's everyday vocabulary, he is apt to forget that they may not be a part of the vocabulary of his reader, at any rate not in the special sense in which he uses them. Consider a term like "puddle." Everyone knows this word in the familiar sense, but not everyone knows that in the metallurgical sense it means a mass of molten metal. Or take "quench" in the same field. Quenching a metal by immersing it in water or oil bears some relation, perhaps, to quenching one's thirst, but it is a distant relationship.

Every field of engineering and science has a great many of these simple words which have been given specialized meanings. Examine the following list (you could probably add a number from your own experience):

apron	:	as on a lathe, the vertical place in front of the carriage of a lathe. This term is also used in aeronautics, navigation, furniture, textiles, carpentering, hydraulics, plumbing, with different meanings in each field.
backlash	:	play between the teeth of two gears which are in mesh or engaged. Not quite the same thing the word would mean to a fisherman!
blooms	:	heaving semifinished forms of steel.
chase	:	iron frame in which a form is imposed and locked up for the press.
cheater	:	an extension on a pipe wrench.
Christmas Tree	:	the network of pipe at the mouth of an oil well. Also red and green lights in a submarine control room to show closed and open passages.
diaper	:	a form of surface decoration used in art and architecture consisting of geometric designs.
dirty	:	to make ink darker.
dwell	:	(of a cam) the angular period during which the cam follower is allowed to remain at its maximum lift, and in printing for the slight pause in the motion of a hand press or platen when the impression is being made.

* Our phrase "familiar words for unfamiliar things" is not wholly accurate. Sometimes a well-known word is unfamiliarly applied to a well-known thing, and hence needs explanation. In anatomy, for example, the word "orbit" (a familiar word) means what most people call "eye socket" (a familiar thing).

freeze	:	seizing of metals which are brought into intimate contact
galling	:	a characteristic of metals which causes them to seize when brought into intimate contact with each other.
lake	:	a compound of a dye with a mordant.

This somewhat haphazard list of terms—it could be extended at length—will serve to suggest the nature of the terms we have in mind. The reader of a report may not persist in confusing the everyday meaning of such terms with the technical sense they may have in a particular context, but there is not much doubt that at the instant he first sees a term of this sort (unless he is a specialist in the same field of work being discussed) he will think of its common meaning. Almost in the same instant he may recognize that the common meaning cannot be what the term denotes in its present context, and he may then recall its specialized meaning; or he may not, depending on his familiarity with the subject matter. In any event, the writer must be alert to the need for defining such terms.

UNFAMILIAR WORDS FOR FAMILIAR THINGS. A moment ago we condemned the writer who prefers to use big and pretentious words for referents with which his reader is familiar. Such a practice should always be condemned if a simple, familiar term exists which means the same thing. But an unfamiliar word for a familiar thing may be used if there does not exist any simple, familiar term for it. Both convenience and accuracy justify it. Suppose you were writing on the subject of hydroponics. You can easily imagine addressing readers who know that plants may be grown without soil, in a chemical solution, but who are unfamiliar with the technical term "hydroponics." Since there isn't a simple, familiar word for this process, you would scarcely want to give up the word "hydroponics" for an awkward, rather long phrase. Your solution is simple: you use the convenient term but you provide a definition. Let's take another example. Suppose an electrical engineer were writing about special tactical electronic equipment making use of direct ray transmission. It is not likely that he would be satisfied to use the phrase "short wave" if he were dealing specifically with, say, the 300 to 3000 megacycle band. On the contrary, he would prefer the phrase "Ultra High Frequency" (UHF). Similarly, a medical man might prefer, in the interests of precise accuracy, the term "analgesic" to the simple word "painkiller."

You will have to judge whether your subject matter demands the use of such terms and whether they are familiar to your readers or not. If they are needed, or if they are justifiably convenient, and

you decide that your readers do not know them, you should define them.

UNFAMILIAR WORDS FOR UNFAMILIAR THINGS. This category, unfamiliar words for unfamiliar things, embraces most of those words that are commonly thought of as being "technical" terms. They are the specialized terms of professional groups; big and formidable looking (to the nonspecialist), they are more often than not of Greek or Latin origin. Terms like "dielectric," "hydrosol," "impedgance," "pyrometer," and "siderite," are typical. We do not want to suggest that a static, precise list could be set up in this group, but since it is the reader's response which determines the category into which a word falls, a great many of the terms which constitute the professional language of any special science or branch of engineering would for the nontechnical reader stand for unfamiliar things. These same words, however, when used by one expert in talking or writing to another expert would be familiar words for familiar things. It is important to remember, on the other hand, that the "nontechnical reader" does not necessarily mean the "lay reader," for even an expert in one branch of science or engineering becomes a nontechnical reader when he reads technical writing in a field other than his own.

So far our interest has been in the problem of what needs to be defined. We can sum it up this way: you need to define (1) terms familiar to your reader in a different sense from that in which you are using them, (2) terms which are unknown to your reader but which name things which actually are familiar to him, or at least things which can be explained simply and briefly in readily understandable, familiar terms, and (3) terms which are unfamiliar to the reader and which name scientific and technical things and processes with which he is also unfamiliar. With these facts in mind about what to define, we can more intelligently consider the problem of how to define.

Methods of Definition

Before discussing the methods of definition, we want to remind you that insofar as it is possible to use simple, familiar terminology, the problem of definition may be avoided entirely; in other words the best solution to the problem of definition is to avoid the need for it. When it is necessary, however, there are two methods or techniques which may be employed. The first may be described as informal; the second as formal. The second takes two forms: the sentence definition and the extended or amplified definition article. Each of these techniques has its own special usefulness.

INFORMAL. Essentially, informal definition is the substituting of a familiar word or phrase for the unfamiliar term used. It is, therefore, a technique that can be employed only when you are reasonably certain that it is the term alone and not the referent which is unfamiliar to the reader. You must feel sure, in other words, that the reader actually knows what you are talking about, but under another name. Thus you might write ". . . normal (perpendicular) to the surface . . ." with the parenthetical substitution accomplishing the definition. Or "dielectric" might under certain circumstances simply be explained as a "nonconductor." Or "eosin" as "dye."

Instead of a single-word substitution, sometimes a phrase, clause, or even a sentence may be used in informal definition. Thus dielectric might be informally explained as "a nonconducting material placed between the plates of a condenser," or eosin as "a beautiful red dye." Or you might use a clause, as "eosin, which is the potassium salt of tetrabromo-fluorescin used in making red printing ink." In very informal, colloquial style, you might prefer a statement like this: "The chemical used in making red ink and in coloring various kinds of cloth is technically known as 'eosin.'" Or "When you use rubber insulating tape in some home wiring job, you are making use of what the electrical engineer might call a 'dielectric.'"

There are several general facts we should note about such definitions. First, they are partial, not complete, definitions. The illustrations just given, for instance, do not really define dielectric or eosin in a complete sense. But such illustrations are enough in a discussion where thorough understanding of the terms is not necessary and the writer merely wants to identify the term with the reader's experience. Second, informal definitions are particularly adapted for use in the text of a discussion; because of their informality and brevity, they can be fitted smoothly into a discussion without seriously distorting its continuity and without appearing to be serious interruptions. Third, we should note that when the informal definition reaches sentence length, it may not be greatly different from the formal sentence definition to be discussed in the next section. It lacks the emphasis, and usually the completeness, however, which may be required if a term names an idea or a thing which is of critical importance in a discussion. In short, if you want to make certain that your reader understands a term, if you think the term is important enough to focus special attention on it, you will find the formal sentence definition, and perhaps the amplified definition, or article of definition, more effective.

FORMAL SENTENCE DEFINITION. We have seen that informal definition does not involve the application of an unchanging, rigid

formula; rather, it is an "in other words" technique—the sort of thing we all do frequently in conversation to make ourselves clear. With formal definitions the situation is different. Here a logically dictated, equationlike statement is always called for, a statement composed of three principal parts for which there are universally accepted names. These are the *species*, the *genus*, and the *differentia*. The species is the subject of the definition, or the term to be defined. The genus is the family or class to which the species belongs. And the differentia is that part of the statement in which the particular species' distinguishing traits, qualities, and so forth are pointed out so that it is set apart from the other species which comprise the genus. Note this pattern:

Species =	*Genus* +	*Differentia*
Brazing is	a welding process	wherein the filler metal is a nonferrous metal or alloy whose melting point is higher than 1000° F but lower than that of the metals or alloys to be joined.

Defined as a process, then, formal definition involves two steps: (1) identifying the species as a member of a family or class, and (2) differentiating the species from other members of the same class.

Don't let these Latin terms worry you. Actually the process of working out a formal definition is both logical and natural. It is perfectly natural to try to classify an unfamiliar thing when it is first encountered. In doing so, we simply try to tie the thing in with our experience. Suppose you had never seen or heard of a micrometer caliper. If, when you first saw one, a friend should say—in response to your "What's this?"—that it is a measuring instrument, you would begin to feel a sense of recognition because of your familiarity with other measuring instruments. You still would not know what a micrometer is, in a complete sense, but you would have taken a step in the right direction by having it loosely identified. To understand it fully, you would need to know how it differs from other measuring instruments, like the vernier caliper, the rule, a gauge block, and so on. In all likelihood, therefore, your next question would be, "What kind of measuring instrument?" An accurate answer to this question would constitute the differentia. Assuming that your friend had the answers, he would then probably tell you something about the micrometer's principle of operation, its use, and the degree of accuracy

obtainable with it. Were it not for the fact that you had it in hand, he would also undoubtedly describe its shape, for physical appearance is a distinctive feature of the instrument. To be quite realistic about our hypothetical instance, we must admit that he would probably tell you more than is essential to a good sentence definition; and he would probably use more than one sentence. But if he were to sift the essential distinguishing characteristics of the micrometer from what he had said about it and put them into a well-ordered sentence, he would have made a formal sentence definition—something like this, no doubt: "A micrometer is a C-shaped length gauge in which the gap between the measuring faces is minutely adjustable by means of an accurate screw whose end forms one face."

Natural as the process of identifying and noting the particular characteristics of something new may be, it must not be done carelessly. Let's take another look at some of the problems of handling the genus and differentia, respectively. The first step in the process of formal definition is that of identifying a thing as a member of a genus, or class. It is important to choose a genus carefully so as to limit the meaning of the species and give as much information as possible. In other words, the genus should be made to do its share of the work of defining. You wouldn't have been helped much, for instance, had your friend told you that a micrometer is a "thing" or "device." If a ceramic engineer were to begin a definition of an engobe by saying it is a "substance," he wouldn't be making a very good start; after all, there are thousands of substances. He would get a great deal more said if he were to classify it at once as a "thin layer of fluid clay." With this informative beginning, he would have only to go on to say that this thin layer of fluid clay is applied to the body of a piece of defective ceramic ware to cover its blemishes. Generally speaking, the more informative you can make the genus, the less you will have to say in the differentia. Another way of saying this is that the narrower you can make the genus, the less you have to say in the differentia.

Care must also be taken in carrying out the second step of the process of formulating a sentence definition. Here the important point is to see that the differentia actually differentiates—singles out the specific differences of the species. Each time you compose a statement in which you attempt to differentiate a species, examine it critically to see if what you have said is applicable *solely* to the species you are defining. If what you have said is also true of something else, you may be sure that the differentia is not sufficiently precise. One who says, for instance, that a micrometer is "a measuring instrument used where precision is necessary" will recognize upon reflection

that this statement is also true of a vernier caliper, or, for that matter, of a steel rule (depending, of course, upon what is meant by "precision"). One way to test a statement is to turn it around and see whether the species is the only term which is described by the genus and differentia. Consider this example: "A C-shaped length gauge in which the gap between the measuring faces is minutely adjustable by means of an accurate screw whose end forms one face is a—————— ——." "Micrometer" fills the blank, and if the definition is correct, it is the only term which accurately fills the blank.

All of the foregoing discussion about methods can be reduced to the statement that an accurate limiting genus coupled with a precisely accurate differentia will always ensure a good definition. There are, however, a few specific suggestions about particularly common difficulties that should be added. Do not regard the itemized list that follows as something to be memorized, but as a possible source of help in case of trouble.

1. *Repetition of Key Terms.* Do not repeat the term to be defined, or any variant form of it, in the genus or differentia. Statements like "A screw driver is an instrument for driving screws" or "A caliper square is a square with attached calipers" merely bring the reader back to the starting point. These illustrations may be so elementary as to suggest that this advice is unnecessary, but the truth is that such repetition is not at all uncommon.

There are, however, some occasions when it is perfectly permissible to repeat a part of the term to be defined. For instance, it would be perfectly permissible to begin a definition of an anastigmat lens, "An anastigmat lens is a lens . . ." if it could be assumed that it is the *anastigmat* lens and not all lenses that is unfamiliar to the reader. Or a definition of an electric strain gauge might contain the word "gauge" as the genus. In these instances, it is obvious that the repeated word is not an essential one.

2. *Qualifying Phrases.* When a definition is being made for a specific purpose, a common practice in reports, limitations should be clearly stated. For example, an engineer might write, "Dielectric, as used in this report, signifies . . ." and go on to stipulate just what the term means for his present purpose. Unless such limitations are clearly stated (usually as a modifier of the species) the reader may feel —and rightly so—that the definition is inacccurate or incomplete.

3. *Single Instance, or Example, Definitions.* In an amplified definition, as we shall see in the following section, the use of examples, instances, and illustrations is fine; they help as much as anything to clarify the meaning of a term. But the single instance or

example is not a definition by itself. "Tempering is what is done to make a metal hard" may be a true statement but it is not a definition. So it is with "A girder is what stiffens the superstructure of a bridge." In general, guard against following the species with phrases like "is when" and "is what."

4. *Word Choice in Genus and Differentia.* Try as much as possible not to defeat the purpose of a definition by using difficult, unfamiliar terminology in the genus and differentia. The nonbotanist, for instance, might be confused rather than helped by "A septum is a transverse wall in a fungal hypha, an algal filament, or a spore." And everyone remembers Samuel Johnson's classic: "A network is any thing reticulated or decussated, at equal distances, with interstices between the intersections."

Amplified Definition. Although brief informal definitions or sentence definitions are usually adequate explanations of the unfamiliar in technical writing, there are occasions when more than a word, phrase, clause, or sentence is needed in order to assure a reader's understanding of a thing or idea. If you think that a sentence definition will still leave a number of questions unanswered in the reader's mind—questions that he ought to have answers to—then an amplified or extended definition is called for.

A term like "drift meter" provides an example. A formal sentence definition goes like this: "A drift meter is an instrument used in air navigation to measure the angle between the heading of a plane and the track being made good." It is easy to imagine a reader who would be dissatisfied with this as an explanation, especially if it occurred in a report particularly concerned with the subject of aircraft instruments. He might very well ask, How does it work? What does it look like? What are its parts? and so forth. Answers to questions of this sort would result in an amplified definition. Here is what the author of the above sentence definition said in his discussion of the term:

> The simplest form of drift meter consists of a circular plate of heavy glass set in the floor of the cockpit in front of the pilot. The plate may be rotated within a ring on which degrees of angle are marked to the left and right of a zero mark. This zero point is in the direction of the forward end of the longitudinal axis of the plane. The plate has a series of parallel lines ruled on it. With the plane in level flight the pilot can look down through the plate and rotate it until objects on the ground are moving parallel to the lines. Under these conditions the lines on the plate will be in the direction of the track being made good, and the angle between the heading and this track may be immediately read on the scale.
>
> Many modern and complicated types of drift sights have been de-

> vised but all of them operate on the fundamental principle described above. In some modern drift sights, a gyroscopic stabilizing system holds the grid lines level even though the plane is not flying level. Astigmatizers are frequently incorporated to assist in measuring drift angle, particularly when flying over water.
>
> In some modern drift sights a system is incorporated so that ground speed may be determined. A pair of wires is marked on the grid, perpendicular to those set parallel to the apparent motion of the ground. The time required for an object on the ground to move from one of these wires to the other will be proportional to the ground speed. The distance of the plane from the ground must be accurately known, and the objects observed must be directly below the plane to obtain an accurate value of ground speed.*

There is no single way to go about amplifying a definition. You must use your own judgment in determining how much needs to be said and what needs to be said. To give you some notion of what other writers have found useful, however, we will present the following list of techniques, a list which is in no sense prescriptive but merely suggestive:

1. *Further Definition.* If you think that some of the words in a definition you have written may not be familiar to your reader, you should go on to explain them (some readers, for example, might like to have the word "astigmatizers" explained in the above definition of drift meter).

2. *Concrete Examples, Instances, and the Like.* Since sentence definitions are by their very nature likely to be abstract statements, they do not contain concrete examples of the thing being defined. It helps, therefore, to give the reader some specific examples. As a matter of fact, this technique is probably the best of all.

3. *Comparison and Contrast.* Since we tend to identify—or try to identify—new things and experiences in relation to those we already know, it helps to tell a reader that what you are talking about is like something he already knows. Remember that the relationship must be one of the unfamiliar to the familiar. If you were attempting to explain what a tennis racket is to a South Sea islander, it wouldn't help much to compare it to a snow shoe! On the other hand, it may be better to stress the differences between the things compared. See (5), page 66.

4. *Word Derivation.* It rarely happens that information about the origin of a word sheds much light on its present meaning, but sometimes it does and the information is nearly always inter-

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* *Van Nostrand's Scientific Encyclopedia* (2d ed.; New York, 1947), p. 481. Quoted by permission of D. Van Nostrand Company, Inc.

esting. Take the term "diastrophism" for instance. It comes from the Greek word *diastrophe* meaning "distortion" and ultimately from *dia* meaning "through" and *strephein* meaning "to turn." Thus the word appropriately names the phenomenon of deformation, that is, "turning through" or "distortion" of the earth's crust which created oceans and mountains. As you know, etymological information may be found in any reputable dictionary. Whether you use it in developing a definition or not, it is worth noting.

5. *Negative Statement.* Negative statement appears in many books as one of the possibilities for developing a definition. Sometimes it is called "obverse iteration," sometimes "negation," and sometimes "elimination." Whatever it is called, you should realize that you will never really get anywhere by telling what something is not. But in some cases you can simplify the problem of telling what something *is* by first clearing up any confusion the term may have in the reader's mind with closely related terms. You might, for instance, say that a suspensoid is not an emulsoid, that the former is a colloid which is dispersed in a suitable medium only with difficulty, yielding an unstable solution which cannot be re-formed after coagulation, while the latter is a colloid which is readily dispersed in a suitable medium and which may be redispersed after coagulation.

6. *Physical Description.* We mentioned earlier that you could scarcely give a reader a very thorough understanding of a micrometer without telling him what it looks like. Note the treatment of drift meter. So it is with virtually all physical objects.

7. *Analysis.* Telling what steps comprise a process, or what functional parts make up a device, or what constituents make up a substance obviously helps a reader. This technique is applicable to many subjects: a breakdown of a thing or idea permits the reader to think of it a little at a time, and this is easier to do than trying to grasp the whole all at once.

8. *Basic Principle.* Explaining a basic principle is particularly applicable to processes and mechanisms. Distillation processes, for instance, make use of the fact that certain liquids vaporize at different temperatures.

9. *Cause and Effect.* Magnetism may be defined in terms of its effects. In defining a disease, one might very well include information about its cause.

10. *Location.* Although of minor importance, it is sometimes helpful to tell where a thing may be found. Petalite, for instance, is a rare mineral found only in Sweden; the island of Elba; Bolton, Massachusetts; and Peru, Maine.

The foregoing list is not intended to exhaust the possibilities for amplifying a definition. Anything you can say which will help the reader comprehend a concept is legitimate. We have seen mention of authorities' names (in a definition article on the incandescent lamp, it would be natural to find Edison's name mentioned), history of a subject, classification, and even quotations from literature on a subject, all employed. Nor should every one of these techniques be employed in any given case, necessarily; often only a few of them would be pertinent. You will have to depend upon your own judgment to decide how much you need to say and what techniques are best suited in a specific situation.

Two organization patterns are possible for amplified definitions. The first pattern begins with the formal sentence definition and proceeds to support it by means of appropriate techniques. A glance at the definition of drift meter given earlier shows that it is organized in this fashion. After the initial sentence definition there follow in combination the simple explanation of basic operating principle, description of the functional parts of the device, and method of use. These are then followed by mention of more complex types of drift meters and reference to special uses. In a general way, this pattern or organization may be regarded as deductive in that it begins with a statement regarded as true and proceeds to the particulars and details. Altogether, it is a method to be preferred over the second, or inductive, pattern of organization which places the sentence definition last, as the conclusion to the evidence presented. The deductive method is to be preferred because there is no point in keeping the reader waiting for information he wants, for where the inductive method is used the issue is in doubt, in a sense, until the last sentence is reached.

Placing Definitions in Reports

Very often it is difficult to decide where to put definitions in reports. There are three possibilities: (1) in the text, (2) in footnotes, and (3) in a glossary at the end of the report, or in a special section in the introduction.

If the terms requiring definition are not numerous and require brief rather than amplified definition, it is most convenient to place explanatory words or phrases in the text itself as appositives (set off with commas or parentheses). If you are not sure whether your readers know a term, or if you feel that some readers will know it and some will not, it is probably best to put the definition in the form of a footnote with some suitable designating mark or symbol after the word itself in the text. If placing definitions in the text would result

in too many interruptions, especially for the reader who may know them, it is a good idea to make a separate list to be put in an appendix. In the event that there are a number of terms of highly critical importance to an understanding of your report, they may be defined in a separate subdivision of the introduction of the report. An introduction to a report on, say, a bridge construction, may contain a statement like this: "Concrete, in this report, will mean . . ." with the rest of the statement specifying the composition of the mix.

The point of all this is that definitions should be strategically placed to suit your purposes and the convenience of your readers. Once you decide on the relative importance of the terms you use and the probable knowledge of your readers, you will find it easy to decide where to put the definitions.

Summary

Definition is needed when familiar words are used in an unfamiliar sense or for unfamiliar things, when unfamiliar words are used for familiar things, and when unfamiliar words are used for unfamiliar things. The question of familiarity or unfamiliarity applies in all cases to the reader, not the writer. Definitions may be either informal (essentially the substitution of a familiar word or phrase for the unknown term) or formal. Formal definitions always require the use of a "sentence definition," which is comprised of three principal parts: species, genus, and differentia. Sometimes it is necessary to expand a formal definition into an article. An article of definition may be developed by either the deductive or the inductive method, the former being generally preferable. Definitions may appear in the text of a report, in footnotes, in a glossary at the end of the report, or in a special section in the introduction. Their proper location must be determined by circumstances.

Suggestions for Writing

1. Determine the proper genus for a definition of each of the following words:

hat	magnetism
table	volt
submarine	book
knife	democracy

2. Write a sentence definition of any five of the following:

gun	green sand mold
pliers	soldering

lubrication	relative humidity
lathe	thermocouple

3. Write a 200- to 300-word article of definition on some concept associated with your major field. Some representative suggestions are contained in list A below. If your technical background is not yet sufficiently broad to justify your selection of a concept like those in list A, choose a more general term like those in list B. Develop your article by the deductive method.

A	B
resonance	automobile
air foil	civil engineer (or electrical, mechanical, etc.)
bridge	profession
functional form	responsibility
porosity or permeability	accuracy or precision
engobe	probable error
laminar flow	
weld	
stress and strain	
capacitance	

6

Description of a Mechanical Device

This chapter brings us to the second of the special techniques of technical writing—the description of a mechanical device. What we mean by "mechanical device" scarcely requires explanation. For the sake of the record we might say that mechanical devices may be either simple or complex, and either large or small. But the principles of the description of a mechanical device are not a function of either complexity or size; they apply equally well in any case. In fact, the general procedure in the description is quite simple, and in practice the chief difficulty lies in framing sentences that really say what you want them to say. There is no more fertile field for "boners." *

The three fundamental divisions of the description are the introduction, the part-by-part description, and the conclusion. Before discussing these divisions in detail, we should like to remind you of

* The following extract from a student paper suggests the possibilities: "The Dragoon Colts were issued to the army and sold to civilians equipped with shoulder stocks that locked into the butts to make short rifles out of them."

two things. The first is that a description of a device almost never constitutes an entire report by itself. For practice in the technique, it is wise to write papers devoted exclusively to the description of a device, but it should be understood that such papers will not constitute reports of a type found in actual use. The second reminder is that what needs to be said in the description always depends on what the reader needs to know. For example, your reader might want to construct a similar device himself. This would require a highly detailed treatment. Or he might be chiefly interested in knowing what the device will do, or can be used for, and desire only a generalized description, like the description of a slide rule which is often included in the manufacturer's directions for its use. The fact is, however, that in actual reports the description of a device is usually so interwoven with other elements that the kind of problem we are discussing here almost solves itself.

The Introduction

Because the description of a device seldom constitutes an article or report by itself, the introduction required is usually rather simple. Nevertheless, it is very important that it be done well. The two elements that require careful attention are (1) introducing the device, and (2) indicating the organization of the description. If these two elements seem insufficient for your purposes, in describing a specific device, see Chapter 11 for further suggestions.

INTRODUCING THE DEVICE. The problem of introducing the device to the reader, or telling him what it is, is essentially a problem in definition, and what we will say about it here has already been anticipated in the previous chapter. Even so, it will be worth while to single out three aspects of the problem for special comment. They can be put into the form of the first three questions that a reader would be likely to ask, if he could: (1) What is the device? (2) What is the purpose of the device? (3) What does the device look like?

1. *What Is the Device?* It has probably already occurred to you that answers to the second and third questions, referring to purpose and appearance, were among the methods listed in the previous chapter for making a definition. And since the question "What is the device?" is simply a request for a definition, it is evident that all three questions are concerned with defining the device. That is one of the reasons why we said that introducing the device is essentially a problem in definition. Now we can put the matter in another way. Introducing the device is essentially a question of defining it, and the

methods chosen should be whatever methods are best suited to the reader, but in any case the purpose and the general appearance of the device must be made clear.

What methods besides comment on purpose and appearance can be used, then, in answering the question, "What is the device?" Any method there is. Sometimes the name alone will do, "fountain pen" for example, for most American readers. Sometimes a substitute word will do, as in this instance: ". . . each of these small boats is equipped with a grains. A grains is a kind of harpoon." Sometimes reference to the principle of operation is helpful. To go further with this line of reasoning would be to review the whole chapter on definition.

2. *What Is the Purpose of the Device?* Very often the statement of the purpose will appear as a natural part of the answer to the first question, as was noted. For example, suppose you were writing about the Golfer's Pal Score-keeper. The purpose is implicit in the name itself, in a general sense. To be more conclusive we might add, "The Golfer's Pal Score-keeper is a small mechanical device designed to relieve the golfer of the necessity of keeping track of his score with pencil and paper." A statement about who uses a device, or other circumstances concerning its use (when, where, and so on), as just illustrated, is often helpful.

3. *What Does the Device Look Like?* It is very important to give the reader a visual image of the device as soon as possible. The image should be general, however, not detailed. There will be time enough for details later on. There are fundamentally two ways to provide this image. One is to describe the general appearance of the device; the other is to compare it to something with which the reader is familiar. Of course you must be careful not to compare an unfamiliar thing to another unfamiliar thing. Reference to the Score-keeper again suggests how illuminating a good analogy can be: "This device is very much like a wrist watch in size and general appearance." To this comparison might be added some such direct description as the following: "It consists of a mechanism enclosed in a rectangular metal case—1 5/16 in. long, 7/8 in. wide, and 1/4 in. thick—to which is attached a leather wristband." In summary, we can say that introducing the device to the reader is essentially a problem of definition, and that reference to purpose and general appearance is of particular value.

INDICATING THE ORGANIZATION OF THE DESCRIPTION. It is possible to divide almost every mechanical device into parts. Such division is an essential part of a detailed description. In the introduction to a description, a statement of the principal parts into which the device can be divided serves two purposes. The first is that it is

an additional way, and an important one, of giving the reader a general understanding of what the device is. From this point of view, what we are saying here actually belongs under the preceding heading ("Introducing the Device"). The second purpose is to indicate the organization of the discussion that is to follow. The reader is always grateful for knowing "where he's at." Since it is a logical necessity that each of the parts be described one at a time, presenting a list of the principal parts, in the order in which you wish to discuss them, is a clear indication of the organization of the remainder of the description. The list of principal parts should be limited to the largest useful divisions possible. The principal parts of a slide rule, for instance, might be listed as the rule, the slide, and the indicator. Later on the rule and the indicator could be broken down into subparts.

The order in which the parts are taken up will normally be determined by either their physical arrangement or their function. From the point of view of physical arrangement an ordinary circular typewriter eraser with brush attached might be divided as follows: (1) the metal framework which holds the eraser and brush together, (2) the eraser, and (3) the brush. The metal framework comes first because it is on the outside. From the point of view of function the eraser might come first; then the brush, which is used to clean up after the eraser; and last the metal framework.

Finally, you should be sure that the list of principal parts is in parallel form. It is hard to make a mistake in this because the list will almost inevitably be composed of names—the names of the parts; nevertheless it might be well to check your list. The list is usually in normal sentence form, like this: "The principal parts of the slide rule are (1) the rule or 'stock,' (2) the slide, and (3) the indicator." But if the parts are numerous, it may be preferable to abandon the sentence form and make a formal itemized list, like this:

The principal parts of the slide rule are the following:

1. The rule or "stock"
2. The slide
3. The indicator

The Part-by-Part Description

The introduction being out of the way, and the device logically divided into parts, we are ready to take up the description of the first part. But the fact is that now, so far as method goes, we start all over again, almost as if we hadn't written a line. For what is the "part" but a brand-new device? The reader wants to know what it is. So we must introduce it to him.

We have divided the slide rule—say—into the rule, the slide, and the indicator, and are about to describe the rule. The first problem is to tell the reader what the rule is, and then to divide it into subparts. The general procedure will be—as before—to define the part, to state its purpose, to indicate its general appearance (preferably with a comparison to an object with which the reader is familiar, perhaps an ordinary foot ruler), and finally to divide it into subparts.

And what do we do with the subparts? The same thing exactly. In other words, the device as a whole is progressively broken down into smaller and smaller units until common sense says it is time to stop. Then each of these small units is described in detail.

By this time you may have a mental image of a chain of sub- and sub-subparts stretching across the room with a detailed description glimmering faintly at the end. That certainly isn't what we want. Nevertheless, we do want to emphasize the value of breaking the device down into parts before beginning a detailed description. But, in the first place, if the breaking-down procedure goes very far before you're ready to describe, it probably means that the principal part with which you started was too broad in scope. You need more principal parts. In the second place, while we do urge the value of this system as a general policy, it is simply not true that all description must be handled in this way. Sometimes, for example, instead of giving a preliminary statement of *all* the subparts that will be described in a given section of the description, it is desirable not to mention a certain minor subpart at all except when you actually describe it.

"Described in detail" means careful attention to the following aspects of the device:

Shape
Size
Relationship to other parts
Methods of attachment
Material
Finish

Each of these matters needn't be labored over mechanically, in the order stated, in every description. Which ones need attention, and what kind of attention, depends—as always—upon the reader and the subject. For instance, let's take the term "material" in the list above. The discussion so far has implied that the material of which a device is constructed is not discussed until the device has been divided into its smallest components. But if you were describing an open-end wrench made of drop-forged steel, it would seem unnatural to wait until you

were taking up one of the smaller parts to let the reader in on the fact that the whole wrench was drop-forged steel.

The same line of reasoning can be applied throughout the description. There is no formula which will fit every situation. The important thing is to comprehend what information the reader needs, and to give it to him in as nearly crystal-clear a form as you are capable of.

The Conclusion of the Description

The last principal function of the description of a mechanical device is to let the reader know how the device works, or how it is used. Emphasis should naturally fall upon the action of the parts in relation to one another. This part of the writing constitutes in effect a description of a process, usually highly condensed (see next chapter).

Summary of the Principles of Organization

The outline below indicates in a general way the organization of the description of a mechanical device. As has been explained, the order of some of the topics listed and the inclusion or exclusion of certain topics depend upon the situation. This outline is to be taken as suggestive, not prescriptive.

Description of a Mechanical Device

I. Introduction
  A. What the device is
  B. Purpose
  C. General appearance (including a comparison to a familiar object)
  D. Division into principal parts
II. Part-by-part description
  A. Part number one
    1. What the part is
    2. Purpose
    3. Appearance (including comparison)
    4. Division into subparts
      a. Subpart number one
        (1) What the subpart is

(2) Purpose

(3) Appearance (including comparison)

(4) Detailed description

(a) Shape

(b) Size

(c) Relationship to other parts

(d) Methods of attachment

(e) Material

(f) Finish

b, c, etc.—same as "a."

B, C, etc.—same as "A."

III. Brief description of the device in operation

Some Other Problems

STYLE. By far the most difficult problem in describing a mechanical device is simply to tell the truth. The writer is seldom in any doubt as to what the truth is; he wouldn't be writing about a device that was not familiar to him. But it is one thing to understand a device, and another to communicate that understanding to somebody else through the medium of words. Only painstaking attention to detail can assure accuracy.

It is probably a mistake, however, to try to be perfectly accurate in the first draft of a description. Write it as well as you can the first time through, but without laboring the details; then put it away for as long as you can. When you read it over again, keep asking yourself if what the words actually say is what you meant. At especially critical points try the experiment of putting what you have said into the form of a sketch, being guided only by the words you have written. Sometimes the results are amazing in showing how the words have distorted your intended meaning.

Every time you see the letters "ing" or "ed" on a word watch out for a booby trap (specifically, a dangling modifier; see Chapter 3). And make sure that every pronoun has an easily identified antecedent.

Finally, don't forget to watch the tense. Usually the entire description will be in the present tense. Occasionally it will be past or future. But almost invariably the tense should be the same throughout the description.

ILLUSTRATIONS. People who like to draw and do not like to write are often loud in argument as to the waste of writing anything

at all when a drawing would do. We ourselves are rather sympathetic toward this attitude; but the trouble consists in deciding when the drawing will do.

There is first of all the question of plain facts. Sometimes, for instance, it is difficult or impossible to show in a drawing how a device functions, or just what the finish of a certain part is like, or how much tension is found on a certain fitting (where a torque wrench might be used). Words are usually much better than drawings for such matters.

There is again a psychological problem. Some people seem to have a greater aptitude for comprehending things in verbal form than in graphic form, and vice versa; just as some people more readily comprehend the language of mathematics than they do the language of words, and vice versa.

Certainly the wisest course is to use every means of communication at your command if you really want to make yourself understood. The corollary is to use discretion; you don't want to swamp your reader with either text or drawings.

One of the minor skills that a technical man should possess is that of effectively relating a written discussion to a drawing. In general, two possibilities are open. One is to print the name of each part of the device on the drawing; the other is to use only a symbol. In other words, if you were discussing the indicator on a slide rule, you might write, "The indicator (see Fig. 1) is . . . ." Or, if you had used only a symbol on the drawing, instead of the name, you might write, "The indicator (Fig. 1-A) is . . . ." If there is only one figure in the report it need not be numbered. You could then write, "The indicator (A) is . . . ."

Information about the form of drawings and other illustrations can be found in Chapter 20.

A problem that comes up in every description is how many dimensions to indicate, both in the text and on the illustration. A decision must be based upon the purpose of the description. For instance, if you anticipate that the description may be used as a guide in construction, then all dimensions should be shown on the drawing, and a good many stated in the text.

ILLUSTRATIVE MATERIAL

The following pages contain two examples of the description of a mechanical device. The first, "Cleveland Open Cup," is a student's description of a relatively simple device. The second description appeared in an article entitled "High-Pressure Apparatus for Compress-

ibility Studies and Its Application to Measurements on Leather and Collagen," issued by the National Bureau of Standards. The second description is concerned with much more complex material than the first.

REPORT ON

THE CLEVELAND OPEN CUP

SUBMITTED TO

Engineering Reports Staff
The University of Texas
Austin, Texas

BY

Richard A. Roe
Junior Petroleum Engineer

November 29, 1950

Cleveland Open Cup

Theoretical Use

The Cleveland open cup is used in determining the flash and fire points of all petroleum products except fuel oils and those products having an open cup flash below 175° F. The flash point of an oil is the lowest temperature at which enough vapor is generated to form an inflammable mixture with air. The fire point is the temperature at which enough vapor is produced so that the oil will burn continuously for five seconds.

Functional Parts

The Cleveland open cup consists of three main parts: the cup with a flange, the handle, and the pilot. The handle is a convenient way of holding the cup when it is hot. The cup is a specially designed container that holds a specific amount of sample. The flange is on the outside of the cup and protects the oil from the gases produced by the open burner. If an open burner is not used to heat the oil, then the flange serves no purpose.

The Cup

The cup (Fig. 1-A) is molded of brass. All edges are perfect and complete circles. The inside of the cup has a highly polished surface that is easy to clean. The inside diameter, measured along the rim, is 2 17/32 inches, and the inside height from center of the bottom to the edge of the rim is 1 11/32 inches. The sides do not meet the bottom at an angle of 90° but are connected by the arc of a circle of 5/64 inch radius. The filling mark is 25/64 inch from the upper rim. The walls of the cup are 7/64 inch thick; while the bottom is 9/64 inch thick. The overall height of the cup, measured on the outside, is 1 31/64 inches. The outside surface is finished to a lesser degree than the inside. The outside diameter, measured just below the flange, is 2 23/32 inches. The lower surface of the flange is 1 9/32 inches from the bottom of the cup, and the width of its lower surface is 5/8 inch. The flange is 1/16 inch in thickness and is joined to the outside of the cup by a connecting piece. The connecting piece is a 45° right triangle that encircles the cup, fitting between the outside edge of the cup and the top of the flange.

The Handl

The handle (Fig. 1-B) is made of brass and an insulation. A rod, 8 1/2 inches in length and 1/8 inch in diameter, is connected to the outside of the cup 1 1/16 inches from the bottom. On the outer end of the rod, 3 inches from the cup, is a beveled piece of wood insulation.

The description of the Cleveland open cup which starts on the opposite page was submitted by a student as a regular assignment in a course in technical writing. We suggest that you read the entire description before reading the comments on it.

The first two sections of this report together constitute the Introduction. Breaking the introduction up into these two sections has probably—in this instance—added to the clarity.

The statement of the purpose of the three main parts and the one "sub" part (the flange) appears here rather than at the beginning of the description of the parts themselves, respectively. Because the parts are few and easy to remember this method works very well here. It has the particular advantage of emphasizing the relationships of the purpose of the parts.

A comparison to a familiar object would have helped here, perhaps something like—"Except for the flange, the cup has much the appearance of a straight-sided, flat-bottomed thermos bottle cap."

Because there is only one figure in the report, it is rather pointless to give it a number. The writer might have said, instead of (Fig. 1-A), something like (see A in Figure). And he could throughout the report have written "in." instead of "inch" or "inches."

The word "while" in this sentence is unnecessary and awkward.

This sentence is awkward and moderately non-parallel. A better version would be, "The flange, which is $\frac{1}{16}$ in. thick, is joined to the outside of the cup by a connecting piece." However, there is another objection as well. The language here could be incorrectly interpreted to mean that the flange was not a molded part of the cup but was a separate piece attached subsequent to the molding.

The word "insulation" in the first sentence in this section is vague. Why not say, "The handle is a brass rod with a wood hand-grip." The next sentence commits the blunder of not saying how the handle is connected to the cup.

The diameter of this piece is ⅞ inch in the middle and tapers to $\frac{3}{16}$ inch on the inside end and is round on the outside end. The insulation is held on the rod by friction.

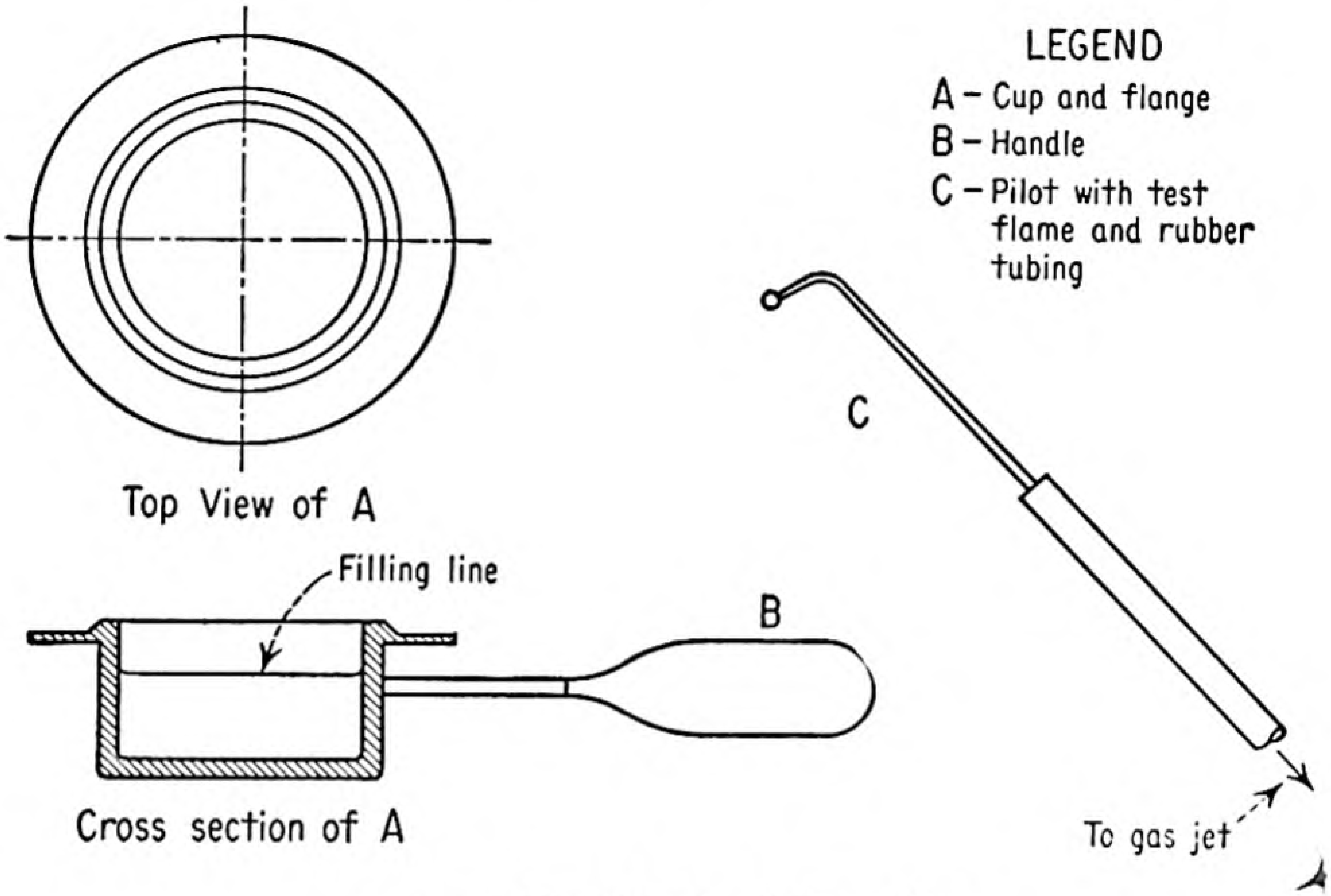

FIG. 1. The Cleveland Open Cup

The Pilot

The pilot (Fig. 1-C) consists of a small bead-like flame produced on the end of a narrow metal tube. The tube is connected to a gas jet by a rubber tube. The metal tube is 10 $\frac{3}{32}$ inches in length and is made of copper. The larger end of the pipe is $\frac{5}{32}$ inch in diameter and tapers to a diameter of $\frac{1}{16}$ inch at the smaller end. The orifice, or opening, at the smaller end is $\frac{1}{32}$ inch in diameter. The pipe is bent at an angle of 45° at a point in the pipe that is between 8½ and 9½ inches from the large end. The test flame produced on the smaller end has a minimum size of $\frac{5}{32}$ inch in diameter.

Operation

The Cleveland open cup is used in the following way to determine the flash and fire point of an oil. The cup is filled to the filling mark with the sample. External heat is applied at an even rate to the center of the bottom of the cup. The pilot, or test flame, is passed slowly over the surface of the sample. When the temperature of the oil reaches the flash point, a blue flash is produced on some part of the surface of the sample. The temperature is increased until the

The next to the last sentence in the section is weak. A better version: "The diameter of this piece, which is ⅞ in. in the middle, tapers to $\frac{3}{16}$ in. on the inside end. The outside end of the hand-grip is rounded. The hand-grip is held on the rod by friction." Do you suppose the word "insulation" was used because it sounded "technical"?

A better version: "The pilot, C, consists of a small bead-like flame produced on the end of a slender copper tube which is connected to a gas jet by a rubber hose."

Is, or is not, the distance of the flame above the surface a critical matter?

The last sentence in the report might better have been incorporated into the first section ("Theoretical Use"). (Incidentally, is the use really "theoretical"?) And, although we can see what the writer

oil ignites and continues to burn for at least five seconds. This temperature is the fire point.

Value

The flash and fire points of an oil are an indication of the ease of ignition of the fire hazard encountered in the handling and use of the oil.

High-Pressure Apparatus for Compressibility Studies and Its Application to Measurements on Leather and Collagen*

By Charles E. Weir

The design and construction of apparatus to be used to measure volume changes of solids (or liquids) between 1,000- and 10,000-atmosphere pressure is described in detail. Calibration of the equipment and its use in determining the compression ($-\Delta V/V_0$) of leather are discussed. The compression of leather between 1,000 and 10,000 atmospheres is reported. The compression between 2,000- and 10,000-atmosphere pressure is approximately 7 percent and appears to be relatively unaffected by moisture content, type of tannage, or sample variation. The compression of all leathers tested is described by the equation $-\Delta V/V_0 = 1.23 \times 10^{-5} (P - 2000) - 5.60 \times 10^{-10} (P - 2000)^2 + 1.35 \times 10^{-14} (P - 2000)^3$.

I. Introduction

A Bureau program of measurement of physical constants of leather and collagen has resulted in a determination of the expansivity of leather and collagen. These experiments also demonstrated that the shrinkage of leather, heretofore considered as analogous to a melting, was in reality a phenomenon occurring over a range of temperatures and resulted in an increase in real volume of the leather-water system studied. Subsequent studies on the rate of shrinkage as a function of temperature, tannage, liquid medium, etc., have been reported. In view of the results an investigation of the effect of pressure on leather

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* Journal of Research of the National Bureau of Standards, Research Paper 2160, Vol. 45, No. 6 (December, 1950).

meant, the sentence as it now stands is illogical. A better version might be, "The flash and fire points of an oil are an indication of its ease of ignition, and hence of the fire hazard encountered in the handling and use of the oil."

In summary, we would say that the over-all organization of this report is good, the introduction is good, the function and general appearance of the major parts are clear but the same is not true of the minor parts, the grammar and syntax are fairly good, the style and diction are weak. There are more merits and more defects than we pointed out. Can you find others? Here is one "lead": the writer did not indicate what the purpose of his description is, or who his imaginary reader was. Are all parts of the description equally suitable for a given reader? What sort of reader would he be?

The description of a high-pressure apparatus for compressibility studies that appears on the facing and following pages is intended for technically trained readers, as the author notes. It is well done. What is printed here is only a portion of the complete article. How this portion fits into the whole may be seen by examining the complete list of subheads shown below:

I. Introduction
II. Apparatus
III. Experimental Method and Calculations
IV. Preparation and Treatment of Specimens
V. Results and Discussion
VI. Conclusions
VII. References

The portion printed here is made up of I and II.

and the shrinkage process was indicated, including a determination of the compressibility of leather for which only estimates have been available.

Experiments involving appreciable pressures are extremely exacting mechanically and have been performed in few laboratories. To obtain information on the apparatus and techniques involved in such measurements, preliminary experiments were conducted on equipment that has been used for many years in the Geophysical Laboratory of the Carnegie Institution of Washington, for measurements at pressures as high as 12,000 bars. Subsequently similar equipment has been constructed at this Bureau and used in conjunction with a hydraulic press in the Geophysical Laboratory. This report deals with a description of the apparatus and a part of the data obtained.

II. Apparatus

In theory the apparatus required is simple; in practice, however, limitations imposed by the strength of materials require exacting machine work and the best of materials. An experiment consists essentially of forcing a piston into a vessel containing the sample under study immersed in a suitable liquid, and recording the depth of penetration of the piston at known *internal* pressures.

The apparatus required consists of—

1. A thick-walled pressure vessel having a smooth bore and a second opening provided to permit measurement of the internal hydrostatic pressure.
2. A leak-proof piston, or plug, which is forced into the bore.
3. A ram designed to drive the plug into the vessel.
4. A leak-proof plug carrying an electrically insulated lead from the internal pressure-gage to the external pressure-measuring equipment.
5. The pressure-measuring equipment.
6. A hydraulic press to actuate the ram.
7. Assorted extractors to remove washers, etc.

The pressure vessel and accessories to be described are made in accordance with designs perfected by workers at the Geophysical Laboratory and are the result of wholehearted cooperation by these workers. The equipment is very similar to that described in considerable detail in 1919 by Adams, Williamson, and Johnston, but it is believed that a more recent highly detailed description of the apparatus, its fabrication, and use may be of interest and value to potential workers in this field.

The pressure vessel consists of a cylinder of SAE 4340 steel—a carbon, nickel, chrome, manganese, molybdenum, alloyed steel having "deep-hardening" properties—5 in. in diameter and 12 in. long. The cylinder, partly shown in figure 1, contains an axial hole 5/8 in. in diameter and 7 in. long. At the bottom of this bore a 2-in.-long hole

The introduction to the apparatus itself answers very clearly the questions of what the device is and what its purpose is but does not provide a good image of its physical appearance. Is this omission a serious one, for the intended reader? A photograph would have helped; but reproduction of photographs is expensive. The statement of the parts of the apparatus is very clear, and the parts are subsequently described in the order listed here.

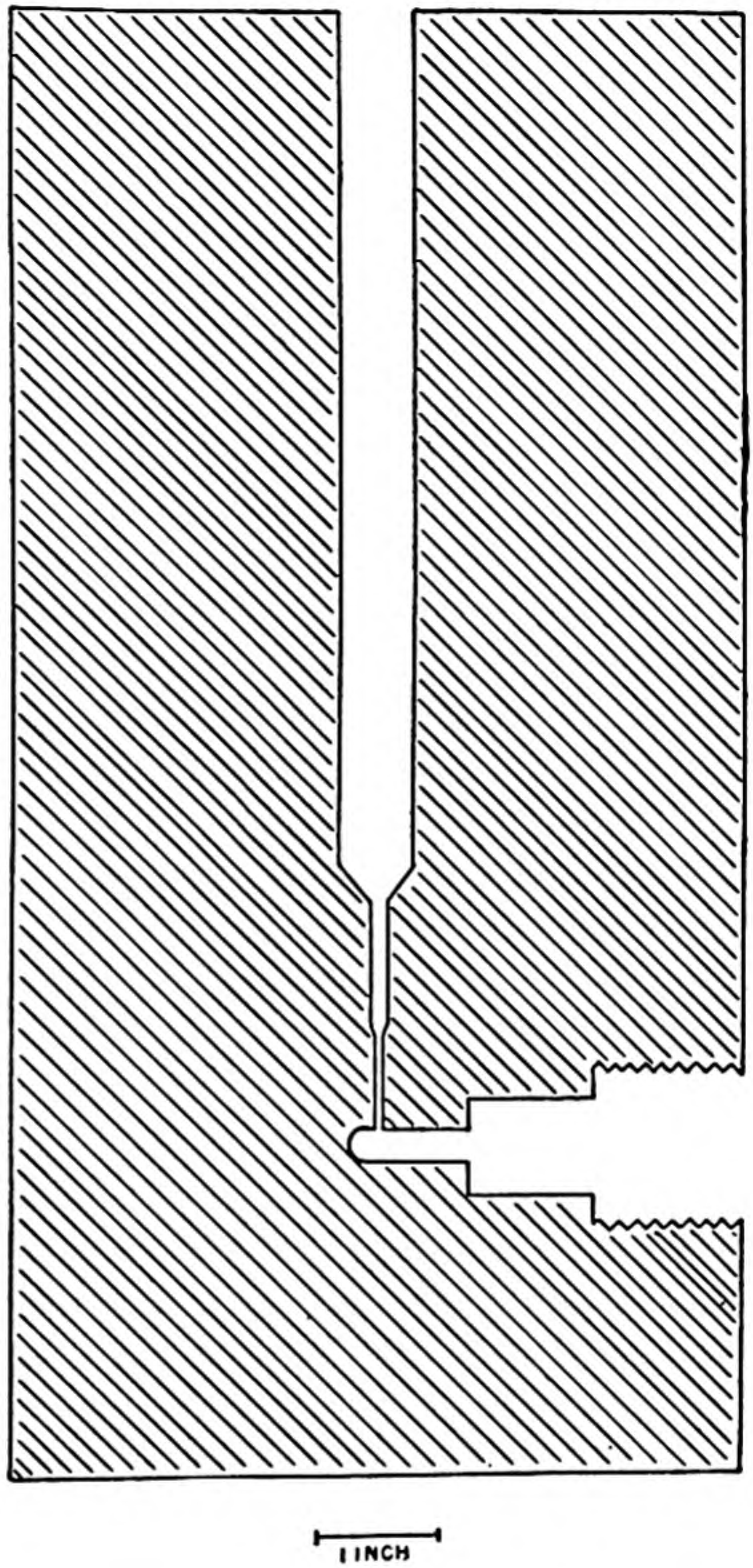

FIG. 1. Section of Pressure Vessel

is drilled, which decreases from ⅛ to 1/16 in. in diameter and serves to connect the pressure gage with the contents of the vessel. An opening for the pressure gage and its plug is made into the side of the vessel to connect with the bottom of the 1/16-in.-diameter axial hole. The gage opening consists of an outer hole 1¼ in. deep designed to fit a bolt 1¼ in. in diameter having 12 threads per inch; a central portion ¾ in. in diameter, 1 in. deep having a flat bottom that meets the wall

The purpose of the pressure vessel, the first part to be described, was stated earlier. As the description of the pressure vessel is begun, facts about shape and size are added to our "over-all view," together with reference to the illustration. A highly detailed description follows.

at right angles; and an innermost portion $\frac{5}{16}$ in. in diameter extending slightly beyond and connecting with the axial $\frac{1}{16}$-in.-diameter hole. After initial machining, this vessel was heat-treated to procure a hardness of Rockwell C-40. The scale produced in the heat treatment was removed, and the $\frac{5}{8}$-in. axial bore that was distorted was ground and lapped to produce a fine finish.

Before the pressure vessel could be used for high-pressure work it had to be subjected to a pressure seasoning followed by a refinishing operation. After the initial machining, the bore of this vessel was observed to increase in diameter by several mils on application of pressure of approximately 10,000 atm. The vessel, however, can be rendered stable, at least in this pressure range, by a seasoning process consisting of subjecting the vessel to an internal pressure far in excess of any subsequently contemplated pressure. For this seasoning, special plugs, which will be described later, were used to fill the openings in the vessel. In seasoning, pressure was applied in increments of 2,000 atm, pressure being maintained for 30 min. after each increment, until a maximum calculated internal pressure of 23,000 atm was attained. At the conclusion of this operation all fittings were found to be damaged, while the vessel had increased noticeably in diameter, externally as well as internally. In the refinishing operation it was necessary to enlarge the bore to 0.696 in. compared to the initial value of 0.630 in. The effectiveness of the seasoning treatment is shown by the fact that the vessel has been in use for several months, withstanding approximately 100 applications of pressures as high as 10,200 atm, with no measurable increase in diameter of the bore.

The movable leak-proof plugs and associated washers are shown in figure 2. Plug A is the type used during seasoning and is designed so that the washers may undergo large lateral expansions to follow the considerable distortion occurring in seasoning. Plug B is used in compressibility measurements. Both plugs are made of Stentor steel, an oil-quenching manganese steel, and consist essentially of a body and stem each $\frac{3}{4}$ in. in length when finished. The stem is $\frac{5}{16}$ in. in diameter, and is threaded for the upper $\frac{3}{8}$ in. of its length with 24 threads per inch to permit extraction. It is very important that the junction of stem and body be filletted to prevent "pinching off" of the stem by the washers. In fabrication, the plug is machined to within 25 mils of the desired size, and heat-treated to procure extreme hardness (at least Rockwell C-60). The hardened piece is ground to size and polished to produce a fine finish, which is designed to minimize high stresses set up in grooves existing in the ground surface. The body of the plug is finished to be $\frac{1}{2}$ to 1 mil smaller than the bore of the vessel. Best results have been obtained with the smaller clearance of $\frac{1}{2}$ mil.

After compression measurements, the frictional force between the washers and the bore is of the order of 800 atms, and the plug must

Before the description of the movable leak-proof pistons, or plugs, is begun, a paragraph is devoted to stating the purpose of having a special plug for seasoning.

In the description of the movable plugs, or pistons, the parts of the plugs are stated first, and then the purpose of each plug is stated. The appearance of the plugs is indicated by an illustration. Subsequently, the plugs themselves are divided into subparts.

be extracted forcibly. In extraction, large stresses are set up in the stem of the plug, and difficulties have been encountered through breaking of the hardened stem. The failures appeared principally when the stem had been threaded prior to hardening, and were probably the result of small cracks in the threads formed in quenching.

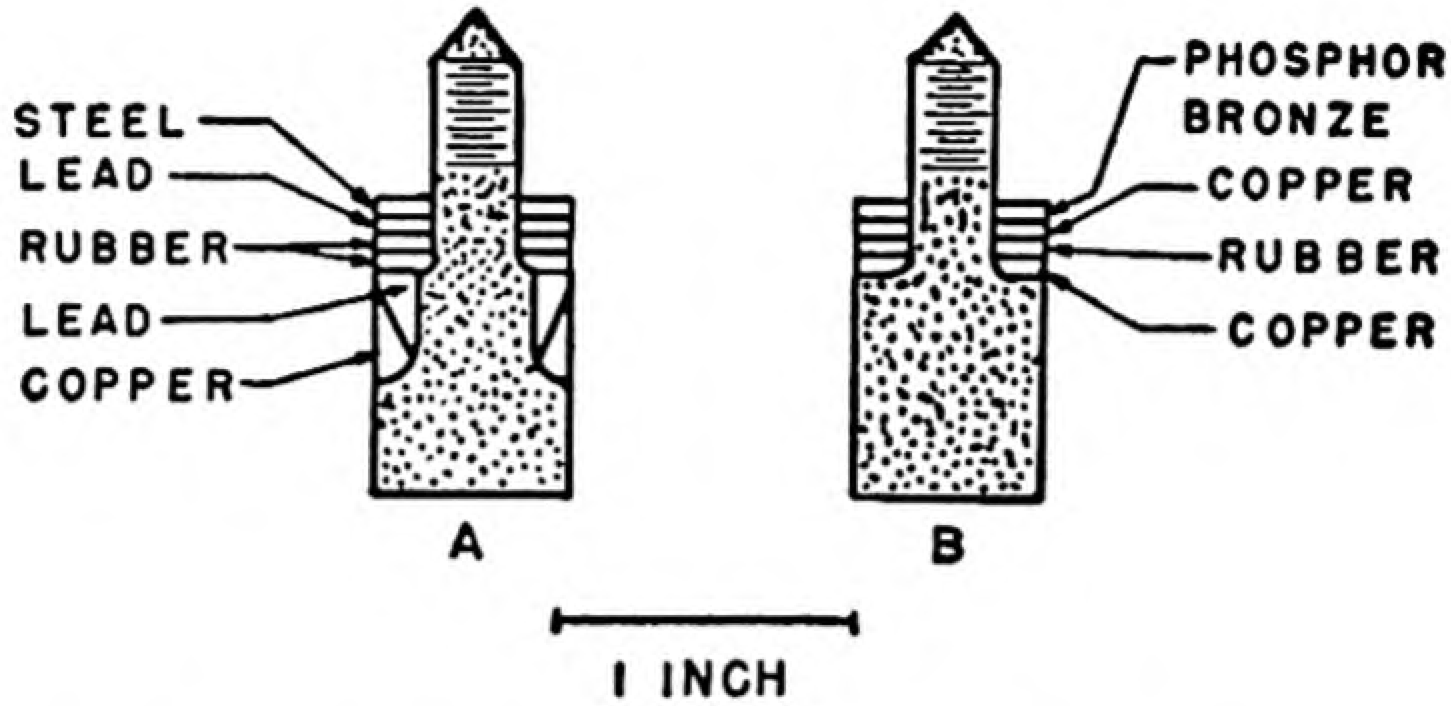

FIG. 2. Sections of Leak-Proof Plugs and Washers

The best procedure has been found to grind the threads on the hardened stem. No failures to date have occurred in plugs made in this manner. It might be advantageous to draw the stem somewhat after finishing, but the necessity of resorting to this treatment has not been demonstrated.

The ram, used to drive the movable plug is shown in figure 3, and consists of a cold-rolled steel head shrunk onto a glass-hard Stentor steel shaft. The head serves to center the ram in the press and is relatively unimportant, since all stresses are borne by the shaft. The rod contains a recess at its lower end, which is finished to provide ample clearance of the stem of the plug that fits into it. Considerable clearance is advisable to prevent snapping the stem if moderate tilting occurs. The diameter of the shaft must be such that lateral swelling under compression will not cause binding in the bore of the vessel. In this instance the shaft is 5 mils smaller than the bore. Barring explosions, the ram travel is seldom greater than 2 in., and the length of the shaft should be kept to a minimum to prevent failure from buckling.

The pressure-gage plug, the insulated electrical lead, and its associated washers are shown in figure 4. This is the most complex fitting required and has caused more failures (including explosions) than all others combined. The plug and lead are both made of SAE 3440 steel hardened to Rockwell C-40.

The electrical lead consists of a rod $4\frac{3}{8}$ in. long, being $\frac{5}{32}$ in. in diameter for $3\frac{1}{2}$ in. of its length, having a shoulder 0.262 in. in di-

In the first sentence devoted to the ram, three things are accomplished: (1) the purpose of the ram is stated, (2) its appearance is suggested through reference to an illustration, and (3) its parts are named (note that the sentence is improperly punctuated and not parallel in structure). Immediately afterward the purpose of the parts is stated.

Here we come to the fourth part that was listed in the introductory list of the parts of the entire apparatus. There is no clear statement of purpose. The purpose is clearly stated in the introductory list, however. Do you find that you remember that statement of purpose well enough not to desire a repetition of it here?

In general, a criticism of the description from here down to the paragraph beginning "The electric equipment used for measuring the

ameter and $\frac{3}{8}$ in. long, and ending in another section $\frac{5}{32}$ in. in diameter and $\frac{1}{2}$ in. long. The tip of this latter section is approximately $\frac{1}{32}$ in. in diameter to facilitate silver-soldering to the gage coil.

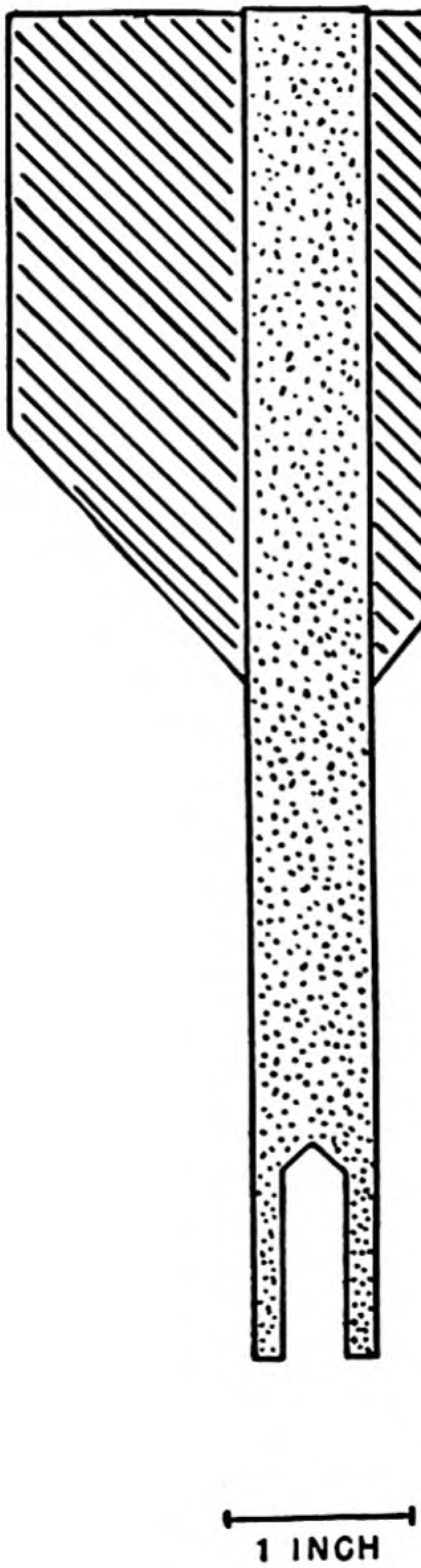

FIG. 3. Section of Ram

resistance of the gage coil . . ." is that there are not enough transitions. The description is logically developed, but the relationship of the parts could be made easier to follow. You can check this point in the following way. Most of the paragraphs concerned start with the name of a part (e.g., "The pressure gage . . ."). As you come to these opening words of a new paragraph, ask yourself how clearly you understand, without stopping to think, exactly what the part is. You will probably feel that in at least some instances a short restatement of the relationship of the part to the other parts would make the reading a little easier.

The gage plug is $1\frac{1}{4}$ in. in diameter and is threaded for $1\frac{1}{2}$ in. with 12 threads per inch. The end of the bolt is machined to two concentric cylindrical surfaces, respectively, $\frac{3}{4}$ in. in diameter and $\frac{1}{2}$ in. long, and 0.615 in. in diameter and $\frac{1}{4}$ in. long. These surfaces

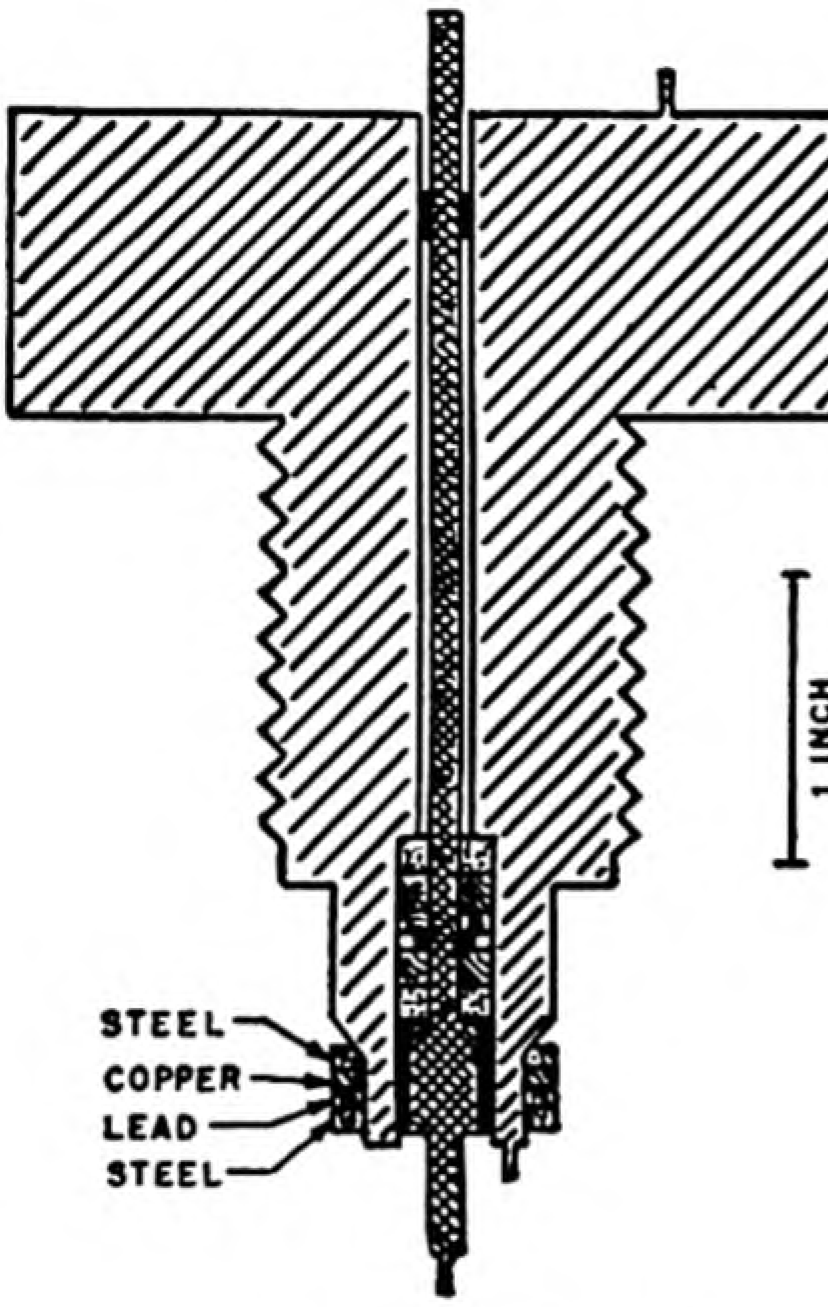

FIG. 4. Section of Gage Plug and Insulated Lead

are connected with a conical frustum $\frac{1}{8}$ in. long, which produces a seal with the packing washers. A recess 1 in. deep and $\frac{5}{16}$ in. in diameter, having a flat bottom with no fillet at its wall, is machined in the end of the bolt, and a $\frac{7}{32}$-in.-diameter hole penetrates the remaining portion of the bolt. A $\frac{1}{4}$-in.-deep hole $\frac{1}{32}$ in. in diameter is drilled in each face of the bolt, and an oversized pin is driven into each hole to serve as a convenient point for securing electric contact.

The insulating washers shown around the electrical lead are in order from the bottom of the cavity: $\frac{1}{8}$-in. limestone, $\frac{5}{16}$-in. outside diameter, $\frac{5}{32}$-in. inside diameter; $\frac{1}{8}$-in. soapstone, $\frac{5}{16}$-in. outside diameter, $\frac{5}{32}$-in. inside diameter; $\frac{1}{8}$-in. Neoprene rubber, 0.317-in. outside diameter, $\frac{5}{32}$-in. inside diameter; $\frac{1}{32}$-in. steel, $\frac{1}{4}$-in. outside diameter, $\frac{5}{32}$-in. inside diameter; $\frac{1}{8}$-in. soapstone and $\frac{1}{8}$-in. limestone as before. This assembly is seated by using a small jig and an arbor press.

Two Bakelite washers not associated with the pressure seal are useful in preventing short circuits of the electrical lead, which may arise from tilting of this lead under pressure. One washer, $\frac{7}{32}$-in. out-

With a figure of the size used, the word "shown" with reference to insulating washers is scarcely accurate! In fact, the usefulness of the drawing is lost because of its size. The authors forgot that reproduced drawings are often greatly reduced in size.

side diameter and $\frac{5}{32}$-in. inside diameter, serves to center the shaft on the low-pressure side, while the other, a thin shell 0.312-in. outside diameter and 0.262-in. inside diameter, protects the shoulder from the plug on the high-pressure side.

In seasoning, a two-piece fitting was used, one being a solid hardened Stentor steel plug having the shape of the end of the plug, the other a $1\frac{1}{4}$-in. bolt to hold the plug in place.

In operation the worker is protected by placing shields around the plug. Although no tendency has appeared toward failure of the threads, even at seasoning pressures, several failures have occurred in which the electrical lead was ejected with high velocity. These failures were all traced to errors in construction or to failure of steel parts. No difficulties, aside from electric short circuits, have been experienced with the arrangement described. The short circuits have resulted from slow extrusion of the limestone insulating washers into the pressure vessel, and use of a fine-grained lithographic limestone apparently has eliminated this difficulty.

The pressure gage consists of a coil of No. 38DSC manganin wire having a resistance of approximately 100 ohms. It is wound in two layers on thin paper, shellacked, and baked for 15 hrs at 125°C. Half-inch lengths of platinum wire are silver-soldered to the ends of the coil and in turn to the insulated electrical lead and the pin in the face of the plug. The gage coil is mounted on the end of the electrical lead, which fits through the coil and provides support.

The properties and seasoning of manganin pressure gages are discussed in detail by Adams, Goranson, and Gibson. Gages used in these experiments were calibrated by using the water-ice VI transition, which occurs at 8,710 atm at 20°C. As the pressure coefficient of manganin is essentially linear, this one point plus the known resistance at 1 atm provides a calibration sufficiently accurate for the present purpose.

The freezing-point apparatus consists of a tube containing distilled water and a few particles of ground glass to facilitate crystallization. The neck of the tube is drawn to a fine capillary, and the tube is inverted and slipped into a steel tube containing several milliliters of mercury. The mercury serves to seal the tube and permit transfer of pressure to the enclosed water. Calibration is performed by subjecting the freezing-point apparatus to pressure in excess of the expected freezing pressure, freezing being noted as a rapid and sudden decrease in resistance of the gage coil. The pressure is then lowered until a moderate rate of rise of resistance corresponding to melting of ice VI is noted. After a period of approximately 1 hr, an equilibrium pressure is attained, but extreme care must be exercised to insure coexistence of water and ice VI at this point. Generally, several equilibrium measurements are required on freezing as well as melting, and such measurements should be in good agreement.

The electric equipment used for measuring the resistance of the gage coil was a G-1 Mueller Bridge. This is an unthermostatted Wheatstone bridge of the shunted-decade type, having a range 0 to 51.111 ohms available in steps of 0.0001 ohm. The method of measurement differs from that used by other principal workers in this field and was suggested by E. F. Mueller of this Bureau.

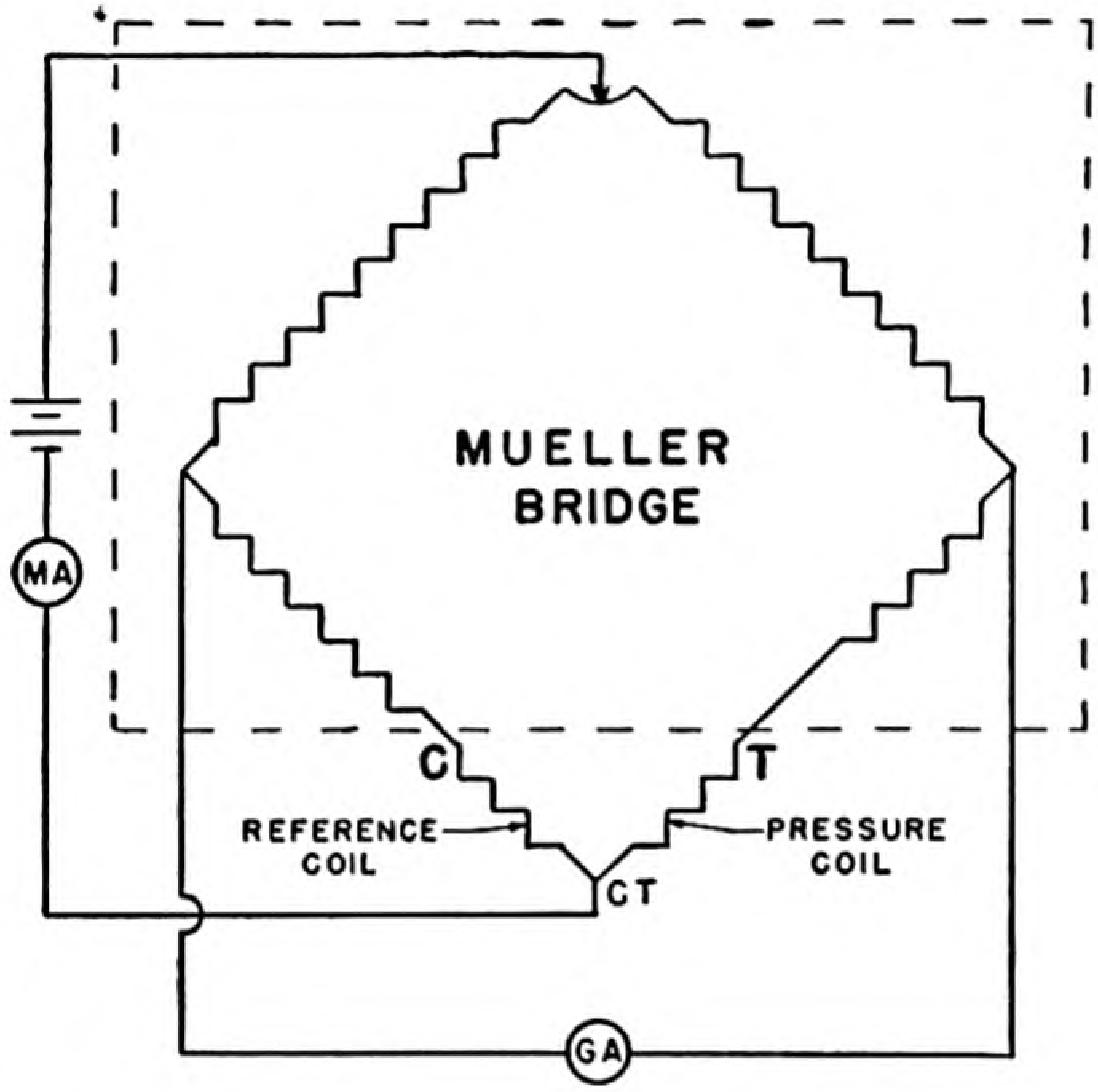

FIG. 5. Schematic Diagram of Pressure-Measuring Equipment

As the pressure gage is approximately a 100-ohm coil, the bridge cannot be used directly to measure the resistance of the coil. Two similar gage coils are used, with one coil—preferably the smaller of the two—being connected directly into one of the arms of the bridge where it serves essentially as a comparison resistor. This coil is immersed in the same liquid as is used for pressure transmission, and is mounted in a well in a large metal block attached to the side of the pressure vessel. The second coil is the pressure coil and is mounted inside the vessel, as described previously. One battery lead to the bridge is made at the junction of the two coils, as shown in the circuit diagram of the electric set-up in figure 5. In operation the bridge measures the difference in resistance of the two gage coils, one of which is subjected to changes in pressure and temperature—

ambient temperature—whereas the other is subjected only to similar temperature changes. As the resistance of manganin increases with pressure, the pressure coil should have the slightly larger resistance to eliminate the necessity for passing through a zero resistance reading. A commutator and mercury contact switch were included in the circuit but were not used in these experiments.

When two 1½-v dry cells were used, the total bridge current was 12 ma, and the gage coil current was 6 ma. With this current a deflection of ⅓ mm for each 0.0001-ohm step was obtained on the galvanometer scale set up at a distance of 2 m. An atmosphere was found to be equivalent to approximately 0.00026 ohm, and the sensitivity was therefore such that a pressure of less than 1 atm could be read directly.

The maximum variation in resistance of the gage coils noted at 1 atm was equivalent to ± 3 atm, and might be caused by the effect of temperature—a maximum temperature variation of ± 2° C occurred during all measurements—on the bridge or on the coils or by the effect of pressure on the gage coil resistance. In the absence of precise temperature control this variation was ignored, as it represented a negligible source of error. No difficulties due to contact resistances in the switches were ever experienced.

No description of the accessories required will be given. A complete set of extractors for every part is required, but the design of such instruments is arbitrary. The extractor generally takes the form of a shaft threaded externally at one end and either externally or internally at the other. A large nut fitting the former end is screwed down against a convenient bearing surface and serves to extract the desired part, which is screwed into the latter end of the shaft. It is of the utmost importance that suitable provision be made for extracting every piece before pressure is imposed, for even though parts may have large clearances they are often found to be solidly joined after a single application of pressure.

The dial gage used to measure piston travel was attached to the top platen of the hydraulic press. This gage had a useful range of 0.400 in. and was graduated in 0.0001 in. Suitable gage blocks were used to extend the range of the gage. Calibration showed a maximum error of ±0.0001 in., and no corrections were applied to the readings.

A press suitable for the measurements was not available at this Bureau, and through the cooperation of the Geophysical Laboratory of the Carnegie Institution of Washington the equipment was set up for use with the 500-ton, hand-operated hydraulic press previously described.

The comments on the extractors and the hydraulic press are not in the order in which those parts were listed in the introduction, but since the comments are brief this difference is unimportant.

Suggestions for Writing

As was implied in the summary comment on "The Cleveland Open Cup," the selection of an imaginary reader for a description of a mechanical device is not always easy. This difficulty is an artificial one not encountered in actual practice, but there is no way to avoid it completely. Give the matter some thought as you examine the suggested subjects below. Indicate on your paper who your imaginary reader is. The least difficulty about the reader will be encountered if you write the description for someone who wants to construct the device—but this may not be the best choice, for you. A good choice is often a reader who, although not interested in details, is curious about the general construction of the device. The most difficulty will arise if you write for someone who (a) wouldn't be interested in details, and (b) is already somewhat familiar with the device.

A torque wrench
An electric soldering iron
A diode electronic tube
A cigarette lighter
A tennis racket
A paper punch
A draftsman's compass
A loose-leaf notebook
A simple tool rack
A hand-made inkstand
A hand-made knife

Include an outline in your description.

7

Description of a Process

A process is a series of actions, and fundamentally the description of a process is the description of action. The action involved in a process may, however, be either one of two types. One type is that in which attention is focused on the performance of a human being, or possibly a group of human beings. A simple example is planing a board by hand; in a description of this process, emphasis would fall naturally upon the human skills required. The other type involves action in which a human operator either is not directly concerned at all, or is inconspicuous. An instance is the functioning of an electrical relay. Large-scale processes, when considered as a whole, are also usually of this second type, even though human operators may take a conspicuous part in some of the component steps. The manufacture of paper is an example.

This chapter will be divided into two main parts, according to these two types of process. But first we can say something about three problems which arise in describing either type of process: that is, the adaptation of the description to the reader, the over-all organization, and the use of illustrations.

Adapting the description to the reader depends, as always, upon

an analysis of the reader's needs. As in the description of a mechanical device, if the reader wishes to use the description as a practical guide, it becomes necessary for the writer to give careful attention to every detail. On the other hand, if he is interested only in acquiring a general knowledge of the principles involved, and has no intention of trying to perform the process himself, or to direct its performance, it is desirable to avoid many of the details, and to emphasize the broad outlines of the process.

The fundamental organization of a process description is simple, consisting merely of an introduction followed by a description of each of the steps in the process in the order in which they are performed, or take place. But this simplicity is usually marred by the necessity of discussing the equipment and the materials used. In building a boat, for instance, the equipment would include hand and power saws, miter boxes, planes, and so forth; and the materials would include lumber, screws, paint, and others. It is not always necessary to mention every item of equipment or every bit of material (it might be taken for granted that a hammer would be useful in building a boat) but no helpful reference or explanation should be omitted through negligence. Sometimes also it is necessary to explain certain special conditions under which the process must be carried out, like the requirement of a darkroom for developing photographic film.

There are basically two ways of incorporating the discussion of equipment and materials into the description as a whole. One is to lump it all together in a section near the beginning; the other is to discuss each piece of equipment and each bit of material as they happen to come up in the description of the steps in the process. The advantage of confining discussion of equipment and materials to a single section near the beginning is that such discussion does not then interrupt the description of the action itself. This method is usually practical if the equipment and materials are not numerous. If they happen to be so numerous or so complex that the reader might have difficulty in remembering them, then the other method of taking them up as they appear in the process is preferable. The fact is, as will be explained in the second part of this chapter, that the second method is by far the most commonly used.

In summary, we can say that a process description is organized as follows, with the qualification that the discussion of equipment and materials may be distributed throughout the description instead of being confined to one section:

Introduction
Equipment and Materials

Step-by-Step Description of the Action
Conclusion (if necessary)

The use of illustrations, the last of the three general problems, needs little comment. Certainly as much illustration should be introduced as can be managed conveniently. It is difficult to represent action graphically, but sometimes a sketch of how a tool is held, for instance, or of how two moving elements in a device fit together can add greatly to the clarity of the text. The general problem of the use of illustration is much the same as in the description of a mechanical device.

PART ONE: PROCESSES IN WHICH AN OPERATOR TAKES A CONSPICUOUS PART

In this division of the chapter we shall have three subjects to consider: the introduction to a process description, the step-by-step description of the action, and the conclusion.

The Introduction to the Description

The introduction to the description of a process is a comprehensive answer to the question, "What are you doing?" (The remainder of the report is largely an answer to the question, "How do you do it?") An answer to the question, "What are you doing?" can be obtained by answering still further questions, principally the following:

1. What is this process?
2. Who performs this process?
3. Why is this process performed?
4. What are the chief steps in this process?
5. From what point of view is this process going to be considered in this discussion?
6. Why is this process being described?

It is not always necessary to answer all of these questions, and it is not necessary to answer them in the order in which they happen to be listed. It will be helpful to consider each question in turn, to get some notion of what does need to be done.

What Is This Process? The reader must be told very early in the report enough about what the process is so that he can grasp the general idea. The way in which he is told depends upon how much he is presumed to know about the process to start with, as well

as upon the nature of the process itself. Again as in the description of a mechanical device, we have come up against the whole problem of definition of the subject of the description, and again we must refer to the chapter on definition for a full treatment of the problem, with the exception of giving some particular attention to the use of comparison and generalized description.

A report written for sophomore engineering students on how to solder electrical connections might start by saying merely, "It is the purpose of this report to explain how to solder electrical connections." This simple statement of the subject would be sufficient. If, however, a report on the same subject were being prepared for a class of high school girls in home economics (who sometimes study such things) it would not be safe to assume that they all knew precisely what the word "solder" means. It would then be wise to write a formal definition accompanied by a comparison to soldered articles which most of them had probably seen, and to similar processes which they would know about. Such a report might begin in the following manner:

> It is the purpose of this report to explain how to solder electrical connections. Soldering is the joining of metal surfaces by a melted metal or metallic alloy. This process may be compared roughly to the gluing together of two pieces of wood. Instead of wood the solderer joins pieces of metal, and instead of glue he uses a melted alloy of lead and tin which, like the glue, hardens and forms a bond. Soldering is a very widely used technique; one evidence of its use which probably almost everyone has noticed is the streak of hardened solder along the joint, or seam, of a tin can of food.

The third and fourth sentences above constitute a comparison to a process with which the reader (the high school girl) would probably be familiar. The last sentence in the example is a reference to a familiar device in which the process has been employed.

The preceding introduction might continue thus:

> The process of soldering consists essentially of heating the joint to a degree sufficient to melt solder held against it, allowing the melted solder to flow over the joint, and, after the source of heat has been removed, holding the joint immovable until the solder has hardened.

This example gives a general idea of the nature of the whole process. You will probably have noticed also that it looks much like a definition of the process, and at the same time like a statement of the chief steps (a subject to which we will come in a few moments). This definition is, as a matter of fact, good enough; and although the list of steps is actually incomplete the missing steps could easily be added.

It is evident, then, that it would be possible to define a process and indicate its purpose, to give a generalized description of it, and to list the chief steps, all in one sentence. Would such compression be advisable? Sometimes; it depends upon the reader. For the high school girl it probably would not be, since we are assuming that she knows nothing of the process. The more leisurely manner in the examples given would provide her a little more time to get hold of the idea.

In short, the question "What is this process?" is simply a problem in definition; and the use of comparison and of generalized description is often particularly helpful.

WHO PERFORMS THIS PROCESS? There is not a great deal to say about this matter of explaining who performs the process, except to emphasize the fact that it is sometimes a most helpful statement to make. For example, a description of the process of developing color film, written for the general public, might be rather misleading unless it was explained that most amateur photographers do not care to attempt this complicated process, the bulk of such work being done by the film manufacturers. Very often the statement about who performs the process will appear as a natural or necessary element in some other part of the introduction. Often no statement is required.

WHY IS THIS PROCESS PERFORMED? It is, of course, absolutely necessary that the reader know why the process is performed, what its purpose is. Sometimes simply explaining what the process is, or defining it, makes the purpose clear. Often the purpose of the process is a matter of common knowledge. There would be no point in explaining *why* one paddles a canoe, although relatively few people know *how* to paddle a canoe efficiently. Sometimes, however, the purpose of a process may not be clear from a statement of what it is, or how it is performed. Then it is necessary to be quite explicit in stating its complete purpose. To take a simple instance—one might explain clearly and accurately how to water tomato plants, how much and in what manner, and still do the reader a disservice by not informing him that if the supply of moisture is not sufficiently regular there will be a tendency for circular cracks to appear around the stem end of the ripening tomatoes.

WHAT ARE THE CHIEF STEPS IN THIS PROCESS? The listing of the chief things that are done in performing the process, the chief steps, is an important part of the introduction. It is important because it helps the reader to form an idea of what the process is before getting into the details of its execution, but it is even more im-

portant because it tells the reader what to expect in the material that follows. It is a transitional device. It prepares the reader for what lies ahead of him. Naturally, it serves the purpose of a transitional forecast best when it appears at the end of the introduction.

The list of steps can actually appear as a formal list, with a number or letter standing beside each step. If this method seems too mechanical, as it usually does, then the steps can be stated in ordinary sentence form, with or without numbers or letters. Care should be taken with punctuation to avoid any possibility of ambiguity or overlapping of steps. The statement of the major steps in the process of soldering an electrical connection might be written as follows:

> The chief steps in this process are (1) securing the materials and equipment, (2) preparing the soldering iron (or copper), (3) preparing the joint to be soldered, (4) applying the solder, and (5) taping the joint.

Observe that itemized parts of the sentence are grammatically parallel, as they should be. The steps should be discussed in the order in which they are listed.

FROM WHAT POINT OF VIEW IS THIS PROCESS TO BE DISCUSSED? WHY IS THIS PROCESS BEING DESCRIBED? These two questions, which are the last two, can be discussed together conveniently. Neither of them is properly concerned with the question with which we started this section on the introduction, "What are you doing?" and perhaps they should not have been included in the original list. Nevertheless, each of them represents an important aspect of the introduction. Each is concerned in its own way with the purpose of the report.

The latter, "Why is this process being described?" calls for a specific statement of purpose: the purpose of the report, not the purpose of the process, which is a different matter entirely. The simplest way to make the statement is, "It is the purpose of this report to . . . ." Many other ways can easily be devised.

The first of the two questions above is likewise related to the matter of purpose, but here the interest is not in why the process is being described; rather it is in why it is being described in a particular way, or from a given point of view. One illustration of this fact is contained in the different ways that were suggested earlier for the writing of the introduction to the report on soldering. In that instance the point of view was implicit in the manner of presentation. There would be no difficulty in seeing at once that the report written for the high school girl was designed to explain the simple process of

soldering so fully that a completely uninitiated reader could successfully use the explanation as a guide. However, it is often wise to state the point of view explicitly, as in the following example:

> The explanation of how to correct the instability of this oscillator will be given in terms of physical changes in the circuit, rather than as a mathematical analysis.

One concludes from this statement that the point of view in the report is going to be practical, the treatment relatively simple. The point of view will perhaps be that of a radio repair man rather than that of an electrical engineer.

So much for the introduction to a description of a process. In this discussion there has been a particular effort to point out what facts the reader of a process description should be aware of when he has finished the introduction. Sometimes almost all of the problems discussed will have to be met by the writer in a single introduction; sometimes only a few. But probably they should all be thought about. Much depends upon who the reader of the report will be, and upon the general circumstances which cause the report to be written.

Of course the writing of introductions may involve many problems not mentioned here at all. In this section we have discussed only those elements which are likely to be involved in the "machinery" of starting off a process description. For a discussion of other aspects of the writing of introductions see Chapter 11.

The Chief Steps

INTRODUCTION. Two problems in organization appear in the description of the chief steps in a process. One problem is how to organize the steps, the other is how to organize the material within each individual step.

The organization of the steps can be dismissed at once. It is chronological, the order of the performance of the steps. Although it is true that there are processes in which two or more steps are, or can be, performed simultaneously, you can usually manage fairly well by explaining the situation plainly, and then taking one step at a time. Just tell the reader your troubles before you start.

The organization *within* the individual steps requires more comment. In regard to both the content and the organization of the description of each individual step, there is one idea that is so useful that it cannot easily be overemphasized. That idea is that each individual step constitutes a process itself. The individual step should, therefore, be properly introduced, and, if necessary, divided into sub-

steps. Its description is essentially a miniature replica of the description of the process as a whole. Furthermore, if a given individual step can be broken down into substeps, then each substep is likewise treated according to the same general principles as the whole process.

Of course it would be easy to go too far with this idea. What we just said should be taken with a little salt. In the introduction to the whole report, for instance, it is often desirable to say something about who performs the process, about the point of view from which the process will be described, and about why the description is being written. Usually in introducing an individual step nothing of this sort need be said. Definition, statement of purpose, and division into parts, on the other hand, require the same attention in introducing the individual step that they do in introducing the whole report.

What is to be said in describing the action itself constitutes an entirely new problem. It is perhaps surprising to reflect that of all that has been said so far in this chapter about how to describe a process, which was originally defined as an action or series of actions, nothing has as yet been said about how to describe the action itself. Everything has been concerned with how to get the action in focus, together with all its necessary relationships. The only point in the whole report at which action is really described is in the individual step. And if there are substeps, then the description of the action drops down to them.

THE DESCRIPTION OF THE ACTION. In describing the action, the writer is under obligation to say everything that the reader needs to know in order to understand, perhaps even to visualize, the process. The omission of a slight detail may be enough to spoil everything. Moreover, there should be care not only in connection with the details of *what* is done, but of *how* it is done. For example, in telling a reader about heating his soldering iron it would surely be wise to tell him that if the tip of it begins to show rainbow colors it is getting *too* hot. And in an explanation of how to calibrate a wide-range mercury thermometer in an oil bath it would be advisable to point out that caution should be observed lest the oil get too hot and the thermometer blow its top off. Keep the reader in control of the action.

A further illustration of the importance of details, and of analyzing the needs of the reader, can be taken from the following incident. A lecturer in physics was speaking to a class of college freshmen and sophomores about the fundamental principles of the electronic tube. He pointed out that three basic elements in the tube are the cathode, the grid, and the plate. The cathode, he said, has a negative charge,

the plate a positive charge, and the electrons flow from the cathode to the plate, passing through the grid, which is between them. He pointed out that the grid usually has a negative charge, and went on to other matters. A goodly percentage of the class left the room wondering how the electrons got past the negative grid. Perhaps you will feel that these people were not very alert, and perhaps they weren't. On the other hand, the lecturer was speaking *to them.*

We started out, in this section, by saying that the content of the description of a process is governed by the reader's need to comprehend every step in the action. There is little more that can be said about the description of the action in the various steps of the process, with one important exception: that is, the style.

STYLE. A general discussion of style in technical reports is given in Chapter 3, and what is said there applies to the description of a process. There is, however, one problem peculiar to the description of a process which is not taken up in that chapter. This problem is the choice of the mood and voice of the predicate, and of the noun or pronoun used as the subject. A good many possibilities are open, but (neglecting the noun or pronoun for the moment) there are three of special importance: the active voice and indicative mood, the passive voice and indicative mood, and the active voice and imperative mood. We shall illustrate each of these three ways, and then comment on them.

1. *Active Voice, Indicative Mood:*

The next step is the application of the solder to the joint. This step requires the use of only the heated iron (or copper), and a length of the rosin-core solder. The solderer takes the iron in one hand and the solder in the other, and holds the iron steadily against the wire joint for a moment to heat the wire. Then he presses the solder lightly against the joint, letting enough of it melt and flow over the wire to form a coating about the entire joint.

2. *Passive Voice, Indicative Mood:*

The next step is the application of the solder to the joint. This step requires the use of only the heated iron, and a length of the rosin-core solder. The iron is held steadily against the wire joint for a moment to heat the wire. Then the solder is pressed lightly against the joint, until enough of it has melted and flowed over the wire to form a coating about the entire joint.

3. *Active Voice, Imperative Mood:*

The next step is the application of the solder to the joint. This step requires the use of only the heated iron, and a length of the rosin-core

> solder. Take the iron in one hand and the solder in the other, and hold the iron steadily against the wire joint for a moment to heat the wire. Now press the solder lightly against the joint. Let enough of it melt and flow over the wire to form a coating about the entire joint.

The essential differences among these three ways can be expressed as the differences in the following three statements: (1) The solderer holds the iron. (2) The iron is held. (3) Hold the iron.

Which one of the three ways is best? It depends upon several factors.

The advantage of the first way, the active voice and indicative mood, is that it provides the reader with the greatest possible assistance in visualizing the action. It is the most dramatic. It comes as close as it is possible to come in words to the actual observation of someone performing the action. The presence of the person who is carrying out the process is kept steadily in the mind of the reader. This technique is without question a very effective one, and its possibilities should not be overlooked. Probably its best use occurs when the following three conditions prevail: (a) the process being described is one which is performed by one person, (b) the description of the process is intended as general information, rather than as a guide for immediate action, and (c) the description is directed to a reader who knows little about the process. If a guide for immediate action is desired, the terse imperative mood may be preferable—although this is a debatable point. And if the reader of the report already knows a good deal about the process in general, he will have little need of aid in visualization.

The disadvantage of using the active voice is that it is likely to become monotonous unless handled with considerable skill. The monotony arises from the repetition of such terms as "the solderer," "the operator" or whatever the person performing the action is called, even though pronouns can be used to vary the pattern a little. Finally, it might be worth noting that, for some curious reason, perhaps because the active voice is not the natural, instinctive way of describing a process, the writer may feel a reluctance tinged with embarrassment when he sets about saying "The operator does this, the operator does that," and so on. There is no particular reason why he should give in to this feeling.

The advantage of the passive voice is that there is no problem about handling this hypothetical operator. The disadvantage is that the positiveness and aid to visualization of the active voice are missing. The passive voice comes naturally. For a process performed by one person, or perhaps even a few persons, a combination of the active

and the passive voices is possibly a good compromise. We do not care to be dogmatic about this.

The advantages of the third way, the active voice and the imperative mood, are that it is concise, easy to write, and a reasonably satisfactory guide for immediate action, so long as the process is not too complex. It is, however, not really a description at all; it is a set of directions. And, because it is a set of directions, there is likely, willy-nilly, to be a slighting of emphasis upon purpose, and a consequent weakness of the report as an explanation of the process. The imperative mood promotes action better than it promotes understanding.

There are numerous possibilities in addition to the three just illustrated. In fact, all the practical possibilities there are can be listed as follows:

Active Voice, Indicative Mood:
The solderer (or "I," "we," "you," or "one") takes the iron . . . .

Active Voice, Subjunctive Mood:
The solderer (or "I," "we," "you," or "one") should (or "must," or "ought to") take the iron . . . .

Passive Voice, Indicative Mood:
The iron is taken . . . .

Passive Voice, Subjunctive Mood:
The iron should (or "must," or "ought to") be taken . . . .

Active Voice, Imperative Mood:
Take the iron . . . .

Almost all of these forms may be found in use occasionally. We will comment on special problems related to a few of them. (1) We don't advise the use of "one," but still less do we advise the use of "you" as a substitute for "one" (for example, in "You take the iron. . . ." or worse, "You take your iron. . . ."). On the other hand, there can be no objection to "you" when its referent is the reader (for example, "You should take the iron. . . ."). But even if there are no objections to the latter use of "you," there is not much to be said in favor of it, and we do not advise its frequent employment. (You will have noticed that we use it often in this text, but we are not describing a technical process. The style of this book is in general more colloquial than that of most technical reports.) (2) The subjunctive mood should be used sparingly. It is a fine form in which to give advice—as we just did. But don't forget the distinction between *describing* and giving advice. (This last sentence contains a

verb in the imperative; does it please you more, or less, than the subjunctive?) (3) It is all right to use different forms within the same process description, but obviously a little discretion is necessary. It is probably best to use only one of the forms throughout if you can make it sound natural and easy. Please note that we did not say, if you can *do* it easily. Good writing is easily read; it is not usually easily written. All in all, the three forms illustrated at paragraph length above (active indicative, passive indicative, and active imperative) are by far the most useful, with the active imperative running a poor third. These remarks refer only to the type of process in which there is a conspicuous operator.

The Conclusion

The last of the major parts of the description of a process is naturally the conclusion. It is not always necessary to write a formal conclusion. Whether one is desirable depends, of course, on whether it will help the reader. Sometimes the reader needs help in matters like the following:

1. Fixing the chief steps in mind (listing them again might help).
2. Recalling special points about equipment or materials.
3. Analyzing the advantages and disadvantages of the process.
4. Noting how this process is related to other processes, or other work that is being done, or reported on.

The writer must analyze his own report and his intended reader to decide whether a conclusion is necessary.

PART TWO: PROCESSES IN WHICH AN OPERATOR DOES NOT TAKE A CONSPICUOUS PART

We turn now to that kind of process in which the human agent is less conspicuous. Such processes as the latter may be of great magnitude, like the building of a large dam, or relatively simple, like the functioning of a tire pump. They are distinguished by the fact that little emphasis falls directly upon the performance of a human being or beings. How does a tire pump work? An answer to this question would be the description of a process; but in that description there would be little need to mention the quality of the performance of the operator.

The fact is that the kind of process requiring little attention to the operator turns up in technical writing more frequently than

does the other kind. The technical man is more likely to be called on for an answer to the question, "How does this work?" than he is to the question, "How do you do this?" So our subject here is an important one, even if—as will appear—our treatment of it is brief.

All that need be considered here is how the description of a process in which the operator does not take a conspicuous part differs from one in which he does. The essential differences are three.

1. Emphasis is altogether on the action—on what happens—and not on the operator and how he performs certain actions.

2. The presentation is usually (not always) in the active indicative, the passive indicative, or a combination of the two. The imperative mood never appears.

3. The terms "equipment" and "material" take on a somewhat different meaning and significance.

Point number one is fairly obvious. Once a train of events has been set in motion, as in a chemical process, interest in the operator who set the events in motion fades. From then on interest lies in what occurs next. In a process of great magnitude like the manufacture of rubber, where hundreds of operators are engaged and where it is obviously impossible to keep an eye on an individual operator, or even a group, it is clear that the emphasis must be on the action itself. The reader is simply not interested in the *who* involved.

In view of this emphasis, it is easy to see that either the active indicative or passive indicative (or both) will likely be used, and that the imperative cannot be used. The passages quoted below illustrate these styles, the first principally in the passive indicative, the second in the active indicative.

> Following the work of Faraday, Ferdinand Carré developed and patented the first practical continuous refrigerating machine in France in 1860. Carré's idea was to use the affinity of water for ammonia by absorbing in water the gas from the evaporator, then using a suction pump to transfer the liquid to another vessel where the application of heat caused the liberation of ammonia gas at a higher pressure and temperature.
>
> Carré's machine is illustrated by the flow diagram in Fig. VI.* In this ammonia-water system, high-pressure liquid ammonia from the condenser is allowed to expand through an expansion valve and the low-pressure liquid then vaporized in the surrounding refrigerated space. In these two steps the ammonia absorption system is exactly like the compression system. However, the gas from the evaporator, instead of being passed through a compressor, is absorbed in a weak solution of ammonia in water ("weak aqua"). The resulting strong

* See p. 411.

> solution ("strong aqua") is then pumped to the generator, which is maintained at high pressure. Here the strong aqua is heated and the ammonia gas driven off. The weak aqua which results flows back to the absorber through a pressure-reducing valve, the highly compressed ammonia gas from the generator is condensed, and the cycle is repeated.

Except for two in the last sentence, the verbs in the preceding paragraph are in the passive indicative. Now consider another account of substantially the same process, this time in the active indicative:

> The process is shown diagrammatically and much simplified in Fig. X.* Beginning with the ammonia-hydrogen loop, the ammonia gas enters the evaporator from the condenser through the liquid trap which confines the hydrogen to its own conduit. In the evaporator it takes up heat from the surrounding space and vaporizes, its gaseous molecules mixing with those of the hydrogen. The addition of the heavier ammonia molecules increases the specific gravity of the vapor, and it sinks down the tube leading to the absorber.
>
> In the absorber, the ammonia dissolves in the countercurrent stream of weak aqua, while the practically insoluble hydrogen, lightened of its burden of heavy ammonia molecules, ascends to the evaporator to again perform its task of mixing with and decreasing the partial vapor pressure of the ammonia.
>
> Taking up the ammonia-water loop, the strong aqua in the absorber flows by gravity to the generator, where the application of heat drives the ammonia out of solution. A vertical tube, the inside diameter of which is equal to that of the bubbles of gaseous ammonia generated, projects below the surface of the boiling liquid. This "liquid lift" empties into the separator, where the ammonia vapor is separated from the weak aqua. The weak aqua then returns by gravity to the absorber to pick up another load of ammonia.
>
> Finally, the ammonia loop, which has been traced as far as the separator, next involves the "condenser," an air-cooled heat exchanger which removes the latent heat from the ammonia gas, converting it into a cool liquid. Here it passes through the liquid trap that marks its re-entry into the evaporator to serve its purpose of cooling the refrigerated space.

In the account of closed-cycle refrigeration as given above, there is an operator, of course, but after he lights the gas flame which starts the process, he definitely takes a back seat, for the process completes itself without any further assistance from him.

Which of the two versions of the process is the better? They are both good. Pay your money and take your choice. And don't fail to ponder on the value of the consistency of point of view illustrated in both versions.

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* See p. 421.

The third of the differences pointed out has to do with a change in the meaning of the terms "equipment" and "material," as these terms are used in the list of the major parts of a description of a process. Where an operator is conspicuously involved, their meaning is clear; he *uses* equipment and materials in carrying out the process. But in the description of a process like those quoted above, there is no operator, and—curiously enough—what in the other kind of process would be simply equipment and materials may now be said to be performing the process! For instance, in a description of how a tire pump works there would be no operator and, instead of being merely the equipment, the pump might be granted the active voice—as in the statement, "The plunger compresses the air in the cylinder. . . ."

Once this simple fact is understood you will have no difficulty. And now we can go on to point out an important fact about process descriptions in actual industrial and research reports. More often than not, in such reports, the description of the device or devices involved (as discussed in Chapter 6) and the description of the process (as discussed in the present chapter) are inextricably intermingled, and often other elements (analysis, classification, and the like) are involved as well. As we have said several times, process description is one of the special techniques of technical writing; it is not a type of report. The complexity found in actual reports does not invalidate the principles discussed in these two chapters, although it naturally makes them more difficult to apply. But that is not the fault of the principles; it is, indeed, only through the principles that the complexity can be ruled, and order created.

Aside from the three differences just discussed, the description of a process in which an operator is conspicuous and of one in which he is not rest upon the same principles.

If, at this point, you have the feeling that there are too many things to be kept in mind in solving the problem of writing a description of a process, don't let the feeling discourage you. To become quite expert in quickly solving these writing problems will naturally take a good deal of practice and experience. But remember that essentially you have just two important things to do: (1) introduce your subject carefully so that your reader will be able to follow you easily when you (2) describe accurately, and in the most effective manner, the steps of the process.

ILLUSTRATIVE MATERIAL

The following pages contain an example of a description of the kind of process performed by one person.

Practical Negative Making*

How to develop your first (or your 1000th) roll of film

The developing and fixing of a film is a very simple process. Anyone can do it easily and cheaply and with very good results. There is, however, one best way to do everything and it is the purpose of this chapter to outline the best way to convert an exposed film into a good set of negatives.

The steps covered are, in order:

1. *Loading the tank.*
2. *Developing the film.*
3. *Rinsing.*
4. *Hardening.*
5. *Fixing.*
6. *Washing.*
7. *Drying and Storage.*

The best method of carrying out each step is described in detail and reasons are given why this or that particular method is recommended. All in all a great many words are used to describe the process, but the amount of talk necessary to tell exactly how it is done does not mean that the process is complicated. Anyone who tries can follow the directions. After a little experience the long list of precautions seems simple and obvious and is followed automatically in practice.

The Photographic Film

A photographic film consists of an emulsion of microscopic silver bromide particles in gelatin, coated on a film of transparent nitrocellulose or cellulose acetate. In making a negative the film is placed in a camera and exposed to the light reflected from some object or group of objects. This exposure produces a "latent" or invisible image. The film is then placed in a developer which converts the latent image into a visible one by changing the exposed silver bromide into silver. The image is then "fixed" or made permanent by putting the film into a fixing bath which dissolves and removes the unchanged silver bromide. After washing and drying, the film is then called a negative because its image, while it has the same outlines as the subject, has the opposite tone values. Thus, the negative is dark where the subject was light, and vice versa.

* From *Modern Developing Methods* (3d ed.; Ringwood, Ill., 1944), pp. 5–14. Reprinted by permission of Edwal Scientific Products Corporation.

This introduction (the first three paragraphs) begins and ends with a statement that the process to be described is simple. The reason for this is, of course, that the writer hopes to encourage people to take up the hobby of developing their own film. There is no question who is to perform this process!

The definition of the subject appears at the end of the first paragraph, in connection with the statement of the purpose of the chapter. It is an unusual, but effective, way to work a definition in.

Some indication of the scope of the description is given. That is, each step will be described in detail.

Here the subject of materials (the film) is taken up.

Negative Making Equipment

The best method of developing roll film is in a spiral-groove tank such as the one illustrated in Fig. 1.* Some of these are made for 35 mm film only, and others are adjustable to take any standard size. The best ones are made of bakelite or stainless steel which are not affected by (nor do they affect) the developer. Hard rubber, if properly compounded, is also satisfactory for tank manufacture, and stoneware or enamelled ware are used for large commercial installations. *The reader is especially warned against using brass tanks* whether nickel or chrome plated, because the plating is usually porous and such tanks often cause the developer to be much more active than it should be, producing fog, dense negatives, and coarse grain.

Once the film is in the tank, development, rinsing, fixing, and washing can all be done without opening the tank or removing the film. The only other equipment needed is a thermometer, a viscose sponge or piece of chamois skin to wipe excess water off the film after washing, and a couple of clips to use in hanging the film up to dry. Various accessories such as agitators, temperature regulators, film drying equipment, etc., are convenient, but distinctly in the luxury class.

For developing cut film or film packs, the spiral groove tanks are not suitable, but there are a number of good tanks on the market for this purpose. Where only a few sheets of cut film are to be developed at one time and where fine grain is not necessary, tray development in a flat, enamelled, glass, or rubber dish is often used. With panchromatic film, however, development must be done in total darkness and the tray method is rather awkward.

Darkrooms and Their Substitutes

Since most of the film used by advanced amateurs today is panchromatic (sensitive to all colors) it must be loaded into the tank in total darkness. If this is done in a darkroom, the user should take precautions to see that it is really dark. Much film has been fogged and streaked by light coming through cracks around doors, in darkroom walls, etc. If in doubt as to whether your darkroom is really dark, go into it and sit in darkness for 15 minutes. Then scan the four walls from various angles and from various positions high and low. If there is the smallest light leak it should be plugged up.

If no darkroom is handy, a changing bag can be used or can be improvised from blankets, tent flaps, raincoats, or whatever is at hand. The writer has used all of these on occasion and, when in the mountains, has even loaded a tank inside a pair of hiking breeches

* Figures have been omitted throughout.

This section and the next ("Darkrooms and Their Substitutes") are both concerned with equipment.

by folding over the top of the breeches and thrusting his arms up the leg openings from the bottom.

Loading the Tank

Loading cut film or pack film into one of the present day tanks is a simple procedure and needs no description. Roll film, however, is sometimes hard to load into the spiral groove tanks because the film tends to stick after it is part way in. To make loading easy, the groove in which the film slides should always be dry. The film will slide more easily if the end entering the groove is cut off square and the first ⅛ inch of film bent back on itself for a moment in the opposite direction from the natural curl of the film. This straightens out the end of the film and cuts down the tendency to catch in the groove.

If the film tends to stick even after this treatment, it can usually be inserted the rest of the way by taking hold of the reel with the left hand as shown in Fig. 2, grasping the film lightly (with the thumb and finger forming a semi-circle) as shown and sliding the film along with a firm but gentle pressure. The reel can be rotated with the left hand at the same time.

Film should always be handled by the edges or the back, to avoid finger prints on the emulsion.

"Soaking" the Film

After the tank is loaded and the lid securely on, all operations can be carried out in daylight, if the tank is really light-tight. If the tank is very small or is of the "apron" type so that there is not much room between the emulsion and the apron or the next layer of film, it is advisable to soak the film in plain water for 2 or 3 minutes before development to prevent adherence of air bubbles and "relax" the film, which if badly curled will sometimes buckle enough to touch the back of the next film layer. *With the larger spiral groove tanks such as the one illustrated, there is plenty of room between successive layers of film and this "pre-soaking" is a waste of time.* Indeed, there have been cases where pre-soaking the film in tap water has led to coarse grain and fogged film, because the tap water contained traces of chemicals which got into the developer and over-activated it. If by chance a fine grain developer is contaminated in this way, it should be immediately thrown out, because it will fog subsequent rolls of film developed in it.

Development

The developer should be cooled (or warmed) to the temperature at which development is to be carried out. The temperature should be measured accurately with a good thermometer which

Now we come to the first of the major steps in the process.

This is the second major step. Notice that, as in step one, the step is actually broken up into two parts. Part two of step one is "'Soaking' the Film." Part two of step two is "Agitation." Two sug-

should be held in the solution for a minute or so before taking a final reading.

The developer should be poured into the tank as rapidly as possible as shown in the accompanying illustration. After development is complete, the developer should be poured out as rapidly as possible and the rinse bath poured in immediately. Developing time should be measured from the moment you *begin* pouring developer into the tank to the moment you *begin* pouring it out. If the tank is filled and emptied as rapidly as possible this method of timing will result in correct development. This is the timing method that is used in working out developing times of all Edwal formulas.

If a bakelite tank is used the variation in temperature during development is seldom more than a degree during the average developing time, and for practical purposes may be neglected. Metal tanks, however, are better heat conductors than bakelite and the temperature may vary several degrees, especially in warm weather. For this reason it is advisable during development to keep a metal tank in a large dish of water which is at the same temperature as the developing solution. If this is not possible, the temperature should be measured at the beginning of development and again toward the end and the developing time actually used should be based on the average temperature rather than the temperature at the beginning.

Agitation

The film should be agitated vigorously at first by swishing the reel back and forth in the tank (Fig. 4). During development, agitation for 10 seconds every 2 or 3 minutes is sufficient.

A mechanical agitator can be used if desired. If the mechanical agitator rocks or twirls the entire tank back and forth, the developing time should usually be cut 10% below the time given for hand agitation. If the mechanical agitator swishes the reel back and forth inside the tank, the developing time can be cut 20%. These figures have been determined for spiral groove tanks of the type shown in the illustrations. For other types of tanks, comparative tests should be run before applying these percentages. If the film is insufficiently agitated, uneven development results, and, with 35 mm films, streaks running down from the sprocket holes often appear in the emulsion.

The Rinse Bath

The best rinse bath for film is distilled water, or plain water which contains 8 or 10 drops of glacial acetic acid per liter. A few crystals of citric acid can be used in place of acetic if this is desired. A strongly acid stop bath should not be used if the developer contains much carbonate or sulphite, as most developers do. If an emulsion that is saturated with sulphite or carbonate is plunged into a

gestions for improvement might be considered here. (a) The use of a transitional phrase or sentence might be wise; something like, "The second major step is the developing." (b) The use of some such system of subheads as the following might make the organization clearer:

Development

Temperature and Timing. The developer should be cooled (or warmed). . . .

Agitation. The film should be agitated vigorously at first. . . .

Incidentally, we wonder why *the film should be agitated vigorously*. Purpose?

strongly acid bath, bubbles of carbon dioxide or sulphur dioxide form in the gelatin and cause pinholes. If, however, plain water or water containing only a few drops of acetic acid is used, the sulphite or carbonate are soaked out of the emulsion and no pinholes result when the film is placed in an acid fixing bath or a chrome-alum bisulphite hardener (which are both strongly acid). The rinse bath should be at the same temperature as the developer.

If a rinse bath is to be used at 75° F. or higher, Edwal Thermo-Salt should be added to prevent undue swelling of the emulsion which would otherwise take place in the highly dilute solution (see section on Hot Weather Development in Chapter III).

The Hardening Bath

Under ordinary conditions, no separate hardening bath is needed. The alum in an ordinary acid-hypo-alum fixer hardens the gelatin sufficiently. If, however, it is necessary to wash the film in warm water or to make it scratch-resistant, a chrome alum hardening rinse is used between the rinse bath and the fixer. A solution of 20 to 30 grams of chrome alum in a liter of water may be used if desired. Such a solution will retain its hardening power as long as it has a purple color when viewed by transmitted Mazda light. When it becomes yellowish green it should be discarded.

A chrome alum-bisulphite bath is generally used for amateur work. The bisulphite serves to prevent scum formation due to accumulation of alkali from the developer. The formula is:

Edwal-291—Chrome Alum-Bisulphite Hardener

	Metric	*U. S. Units*
Water	500 cc.	1 pint
Chrome alum	10 grams	150 grains
Sodium bisulphite	10 grams	150 grains

Film should remain in the above bath for 4 to 6 minutes for complete hardening. This bath should be freshly made, and should be thrown out after a day's use. If it is desired to keep a stock chrome hardener, this may be accomplished by making up separate solutions of chrome alum and bisulphite (40 grams per liter) and mixing equal parts of the two liquids when needed for use.

For those who prefer a prepared chrome hardener we recommend Edwal *New Improved* Chrome Hardener which also contains Edwal Thermo-Salt to prevent emulsion swelling. It is packed in convenient form ready to be dissolved in water.

No definition, and only an indirect statement of the purpose of this step are given. And they are needed.

The Fixing Bath

After the film has been rinsed, and hardened if necessary, it is fixed in an acid-hypo-alum bath. A formula for such a hardening fixer is:

Edwal-204—Acid-Hypo-Alum Fixer

	Metric	U. S. Units
Water (100° to 125° F.)	600 cc.	20 ozs.
Hypo	240 grams	8 ozs.
Sulphite (anhydrous)	15 grams	½ oz.
28% acetic acid	47 cc.	1½ fluid ozs.
Boric acid crystals	7.5 grams	¼ oz.
Potassium alum	15 grams	½ oz.
Cold water to	1 liter	1 quart

Dissolve the chemicals in the order given. Glacial acetic acid (3⅓ drams or 13 cc.) may be used in place of 28% acetic acid if desired. In no case should acid or alum be added to the solution before the sulphite has completely dissolved, since a precipitate of sulphur is apt to form.

Film should be fixed in this bath for at least twice as long as is required to clear the emulsion (i.e. remove the milky appearance by dissolving the silver bromide). For maximum hardening, however, especially after the bath has been used somewhat, film should remain in the fixer for 15 to 20 minutes and this fixing time is recommended even for a fresh bath.

Edwal-204 may be used for films at temperatures up to 75° F. without any supplementary hardening. For processing above 75° F. the film should be hardened in a chrome alum hardener (Edwal-291) before fixing. If this is done the fixer will give satisfactory results up to 90° F. if it is fresh. If the bath is kept at 70° or below, it may be stored for 6 or 8 weeks with perfect safety and may be used over and over until exhausted. For work at 75° or over, a fresh fixing bath should always be used, since with an old fixer, there is a tendency to deposit sulphur in the emulsion and this causes the image to fade during storage.

Prepared Fixers

For those who prefer to use a prepared powder fixer, Edwal Acid Fix is recommended. Edwal Acid Fix contains an anti-precipitant which reduces the tendency to formation of a precipitate during storage and prevents formation of insoluble aluminum salts with developers containing trisodium phosphate.

Here is the first use of the imperative. To our ear, it is not very good here.

Two prepared fixers are also available in *liquid* form. One of these, Edwal Liquid Fix, is a standard speed acid hardening fixer which is diluted with 3 parts of water for use. It is much used by amateurs who prefer not to mix their own fixer. The other, Edwal Quick-Fix, contains a new fixing agent and is used for *high speed* fixing of film. Quick-Fix will completely fix and harden a film in 3 minutes.

A fixing bath should *never* be used:

1. If it tends to froth easily.
2. If a pale yellow precipitate of sulphur has formed in the solution.
3. If it will not clear a strip of film in less than 10 minutes.

All these are signs of exhaustion or the beginning of decomposition and such a fixer is almost certain to spoil the film.

A Chrome Alum Fixer

For work at high temperatures (75° to 90° F.) it is sometimes desired to eliminate the use of a separate chrome alum hardening bath. This can be done if the following chrome alum fixer is used instead of Edwal-204.

Edwal-205—Chrome Fixing Bath

Solution A	*Metric*	*U. S. Units*
Hypo	960 grams	2 lbs.
Sulphite (anhydrous)	60 grams	2 ozs.
Water to	3 liters	3 quarts
Solution B		
Water	1 liter	32 ozs.
Chrome alum	60 grams	2 ozs.
Sulphuric acid (Pure Conc.)	8 cc.	¼ fluid oz.

Mix the chemicals in the order given. Just before using, cool both solutions to 70° F. or lower and pour solution B into solution A with vigorous stirring. If no means of cooling to 70° is at hand, the two solutions may be mixed at higher temperatures (up to 90°) but mixing must be done slowly and with very vigorous stirring. Cold water should be used in making up solution B since if the water is above 125° F. the bath will not harden properly.

Edwal-205 is for a gallon of chrome fixing bath. If less than a gallon is needed, pour 1 volume of solution B into 3 volumes of A.

Imperative again.

For best results, the chrome fixing bath should be made up fresh each time it is used, though it will retain its hardening properties for 10 days to 2 weeks if stored in a cool place. The stock solutions will keep quite well as long as they are not mixed. Stock solution A should be kept in full, tightly closed bottles if it is to be stored for more than 4 to 6 weeks. A modification of Edwal-205 is sometimes used containing 4 ozs. of chrome alum and 2½ ozs. of sulphite in place of the quantities specified. Such a bath gives a more powerful hardening action than Edwal-205 but should not be used after it is two days old.

Film should be fixed in Edwal-205 for 20 minutes at 70°. At higher temperatures the time may be reduced about 10% for each 5° above 70° F. if desired. This fixer exerts a very strong hardening action and film fixed in it can be washed in fairly warm water without damage. The film emulsion becomes very tough and scratch-resistant, and after drying can hardly be scratched with the thumbnail.

Washing and Drying

After the film is fixed it should be washed 20 to 30 minutes in running water at 70° to 75°. F. This may be done either in the tank or in a shallow tray or pan. The water should circulate vigorously enough so that the entire emulsion surface of the film is thoroughly washed in fresh water. After washing, both sides of the film should be gently wiped with a viscose sponge or chamois which has been wet with water and squeezed out. A cloth may be used, but lint is apt to be left on the film.

The film is then hung up to dry by means of a clip at one end, and a second clip is put on the lower end to act as a weight and keep the strip from curling. Drying should be done in a dust-free room. The best drying time is about 20 minutes. If the air is humid and a longer drying time is necessary, no damage is done. It was once thought that a long drying time increased graininess, but tests have shown that if there is any effect it is so slight that it cannot be measured. If the film is dried very rapidly in a blast of hot air, it sometimes curls excessively and there may be a slight coarsening of the grain structure.

With small tanks it is best to take the film completely out of the tank and wash it in a larger vessel, since circulation is apt to be poor and hypo-removal incomplete if washing is carried out with the film in the tank. Also a certain amount of hypo is apt to remain in the groove of the reel and this contaminates the next batch of developer and causes fog along the edges of the film. This groove should be thoroughly washed after the film is removed, whether the film is washed in the tank or not.

Film may be dried more quickly if a rinse containing a wetting agent is used after washing. Allow the well-washed film to drain and

Note the dangling participle.

Indefinite reference of "this."

then soak it for 30 seconds to a minute in a bath made up of ten drops of Edwal Kwik-Wet to a quart of water. Make sure that all emulsion surface is reached by the wetting agent bath. The film may then be hung up to dry and since the water will drain off much more evenly with no individual drops left on the surface, the film will dry in about half the usual time.

For the Beginner

The directions given in the preceding pages are quite detailed and may appear rather awesome to a beginner. For anyone who is about to develop his first roll of film, the following simplified procedure is suggested:

1. Unless you are experienced in handling chemicals, use a prepared developer, hardener, and fixer. For general work we recommend the liquid Super-12 (or the powder form Edwal-12) as a developer, and Edwal Acid Fix or Liquid Fix as the fixer. If extra hardening is desired, use Edwal Chrome Hardener between the rinse bath and fixing. Sizes, prices, etc., are given in the last pages of this book.

2. Load the film into the developing tank as described earlier in this chapter. Always handle film by the edges.

3. Be sure the developer, rinse bath, and fixer are all at 70° (or whatever temperature is specified).

4. Pour in the developer, and agitate the film vigorously. Agitate every 2 or 3 minutes during development.

5. Measure the developing time from the moment you *begin* pouring developer into the tank to the time you *begin* pouring it out. Use the developing time recommended for the film you are using.

6. When development is complete, pour the developer out of the tank, and pour in a rinse bath consisting of a few drops of acetic acid in plain water. Agitate as during development.

7. After 4 or 5 minutes, pour the rinse bath out of the tank and pour in a solution of Edwal Chrome Hardener. Agitate as usual. Allow the film to remain in the hardener for 4 to 5 minutes. (This step may be omitted if extra hardening is not desired.)

8. Pour out the Chrome Hardener and pour in Edwal Acid Fix, or Liquid Fix. Agitate occasionally. Fix 20 minutes.

9. Pour out the fixer and wash the film in running water for 20 to 30 minutes. If the temperature of the wash water is somewhat different from that of the developer, fixer, etc., this does not matter.

10. Rinse film (after washing) for 30 to 60 seconds in a solution of 10 drops of Edwal Kwik-Wet to a quart of water. This eliminates water-spots and cuts drying time in half. Wipe the droplets off both sides of the film with a damp viscose sponge or chamois and hang it up to dry.

Lest there be some misunderstanding, we should like to say clearly that, in the original text, this section follows the preceding section exactly as it does here.

This is an illustration of an extended use of the imperative. Observe that the intended reader, or user, of this section, as compared with the preceding section, is the beginner: the person who would have the least ability to understand the process. The reader here is just going to do what he is told. It should be noted, however, that these directions could scarcely be used independently of the preceding material..

In concluding these comments, we should like to add that, in general, this is a good piece of writing. The introduction is good, the over-all organization is good, and for the most part the writing is

11. After drying, the film may be rolled up for storage in cans, or cut into strips or separate negatives. For prolonged storage, metal containers are recommended.

good too, although you will have noted many inconsistencies in style and abbreviations in addition to other departures from the standards usually followed in careful technical writing. Transitions, the use of subheads, and the organization within individual sections might be improved a bit.

Suggestions for Writing

1. Assuming a college student as a reader, write a description of some laboratory process which he knows he will have to perform. Make this a description which will bring him to understand the process, not a set of directions to be followed blindly. Suggested topics: making a green sand mold, adjusting a transit, converting a voltmeter into a galvanometer, constructing a Wheatstone bridge, determining the flash point and fire point of an oil, analyzing iron ore by the potassium dichromate method, making a proximate analysis of a coal. Include an outline.

2. For a nontechnical reader, write a description of one of the following processes, again with the primary purpose of helping the reader to understand the process: a valve-grinding job, tuning up a motor, sharpening scissors, soldering an electrical connection, parking an automobile (for a "beginner"), paddling a canoe. Include an outline.

3. Write a "set of directions" for any one of the topics above, with the primary purpose of getting the process performed whether the person involved understands what he is doing or not. Indicate who your imaginary reader is.

8

Classification and Partition

Introduction

If you were to list, just as they occur to you, all the terms you could think of which name kinds of engines, you might write down a list something like the following: steam, internal-combustion, in-line, aircraft, radial, diesel, gasoline, marine, automobile, two-cycle, four-cycle, rocket, jet, eight-cylinder, six-cylinder, and so on. Such a list, quite apart from its incompleteness, obviously makes little sense as it stands; it has no order or system. If you were then to experiment with the list further in an effort to bring order and meaning to it, you would probably rearrange the items in the list into groupings, each grouping in accord with a certain way of thinking about engines. In other words, you would list kinds according to a point of view. Thus the term "internal combustion" might suggest a grouping according to where the power-producing combustion occurs and give you two kinds of engines: internal-combustion engines and external-combustion engines, steam engines suggesting the latter. Other terms

of the list would naturally suggest other ways of grouping engines: according to cylinder arrangement, use, number of cylinders, and so on. You would, in fact, be on the way to making a classification of engines, for classification is the orderly, systematic arrangement of related things in accordance with a governing principle or basis. The classifier notes the structural and functional relationships among things which comprise a class.

In recording these relationships, the classifier employs certain conventional terms. Acquaintance with these convenient terms will make the rest of what we have to say easy to follow.

GENUS AND SPECIES. A genus is a class; a species is a subdivision within a class. If "engineering subjects in college" is the genus, then mathematics is a species; if mathematics is the genus, then algebra, geometry, and calculus are species; if calculus is the genus, then differential, integral, and infinitesimal are species. These two terms, genus and species, are very commonly used, but there are many others which can be added to them if a more complex classification is desired. Recent classifications of animal life, for instance, give as many as twenty-one categories, from subspecies through species, subgenus, genus, subtribe, tribe, subfamily, family, superfamily, infraorder, suborder, order, superorder, cohort, infraclass, subclass, class, superclass, subphylum, phylum, and finally kingdom, the broadest group of all. Elaborate classifications like this have the purpose of telling all that is known by man about the structural and functional relationships among the individuals of the classifications.

CLASSIFICATION. The term "classification" has a loose popular meaning, and a more precise technical one. Popularly, classification is almost any act of noting relationships. Technically, classification is the act of hunting down a specimen of all of the different kinds of objects which possess a given characteristic or characteristics. Initially, of course, classification must begin with the recognition that different things possess similar characteristics. Suppose that one day you happened to see a strange creature swimming around in the water, a creature with the body of a horse, feet like a duck, and a tail like a whale (we're thinking of some local statuary). You'd probably only stare; but if you presently saw a second creature just like the first except that it had a tail like a salmon, you'd possibly say, "There's another of *those things!*" And if, soon after, you saw a third, slightly different from the first two, you might be moved to think up a name (like Equipiscofuligulinae) for the whole family and to spend many years thereafter hunting for new species, and giving them names. You would be classifying.

LOGICAL DIVISION. When you got around to sending off some papers to the learned journals on the discovery described above, you would find yourself engaged in logical division. By this time, you would naturally have found all, or at least all you could, of the existing species, and so would have completed your classification. You would write, "The genus Equipiscofuligulinae is made up of seventeen species . . . ." In thus dividing, into seventeen parts, the collection that had previously been made, you would be doing what is technically called logical division. In short, classification and logical division are the same gun seen from opposite ends of the barrel.

In practical report writing it is usually logical division, not classification, that you will be concerned with; nevertheless, the term "classification" is the one you are likely to want to use even where "logical division" is technically correct. You might write, "Tractor engines can in general be classified as full diesel, modified diesel, and gas." This is logical division simply because it is a division, into three groups, of information that was already known. But it is likely that a scientist or engineer would say "classified" rather than "logically divided"—to judge from our own acquaintance with technical literature. For that reason, and for convenience in general, we shall hereafter use the term "classification" to mean either logical division or true classification. And we shall be chiefly concerned with logical division, since the report writer is almost always concerned with dividing up a collection of facts or ideas, in order to discuss them in turn, rather than with hunting down new species. After all, the hunting will necessarily have been done before the writing starts.

You may wonder why, if we're going to use only the term "classification," we bothered to distinguish between it and logical division at all. The reason is twofold: first, just to get down all the facts; and second, to avoid confusion when we go on to the next term on our list.

PARTITION. Partitioning is the act of dividing up a unit into its component parts. The parts do not necessarily have anything in common beyond the fact that they belong to the same unit. A hammer may be partitioned into head and handle. *Hammers* may be logically divided according to the physical characteristics of their heads as claw, ball peen, and so forth. Classification, or logical division, always deals with several (at least two) units. Partition deals with the parts of only one unit. A hammer is a single unit. A hammer head without a handle is not a hammer. The head and the handle are component parts of a single unit. You have probably become familiar with a variety of partitioning in a chemistry course when you

determined the components of a chemical compound. Partitioning is further discussed later on in this chapter.

BASIS. Suppose we go back for a moment to the strange creatures with a body like a horse, feet like a duck, and a tail like a fish or a whale. And suppose we imagine two men discussing them after only a very brief glance as the creatures swam by. The first man, A, catches only a glimpse of the body, and he immediately says, "Why, these animals are clearly related to the horse." But B, who is a little slower, sees only the tail, and he protests, "Not at all! They're obviously fish!" Now, what these men need is a basis of classification. Classified according to (or on the basis of) their main body structure, the creatures are horses. Classified according to their tail structure, they are fish or whales.

Or we might go back to an illustration used at the beginning of this chapter. How should we classify engines? On the basis of power, or use, or the kind of fuel they use, or where the combustion occurs? The manufacturer who is looking for a gas engine to use in the power lawn mower he wants to make and sell would not thank you for a classification of small engines according to the place where the combustion occurs. What basis would interest him? Power? Weight? Cost?

These terms, then, are the ones to remember: genus and species, classification, logical division, partition, and basis. The rest of this chapter will be devoted to a consideration of the times when the techniques of classification and partition may be found useful, what rules govern the use of classification, what rules govern the use of partition, and what particular writing procedures may be involved.

When Is Classification a Useful Technique of Exposition?

The foregoing discussion has suggested why classification is a useful technique of exposition: it permits a clear, systematic presentation of facts. When to use this technique depends on whether a writer is dealing with classifiable subject matter and whether his writing can be made more effective by means of the technique.

To get an idea of when the technique may be usefully employed, let us consider a specific writing problem. Let us suppose a writer has the task of writing about a large number of different vat dyes. Let us also suppose that he needs to inform his readers about their properties so that their applications will be fully understood. He could, of course, proceed by discussing each dye in turn, giving all the pertinent information about the properties and characteristics of dye No. 1, and then of dye No. 2, and so forth. But let us suppose that the writer

knows that there are several points of similarity among the forty or fifty different dyes he has to discuss. He knows, for instance, that they all fall into two groups so far as their derivation is concerned. He knows, further, that some of them are alike in certain respects so far as dyeing behavior is concerned. If these relationships among the dyes are important to an understanding of the use of the dyes, he may decide that the information he has to present will be more meaningful and more readily usable if he classifies the dyes rather than discussing them one at a time. It will be helpful to the reader, in other words, if he points out the relationships which exist among them instead of leaving these relationships for the reader to discover. You may want to turn now to the example at the end of this chapter to see how this problem was actually handled.

Classification, then, is useful when you have a number of like things to discuss among which there are points of similarity and difference which it is important for the reader to understand. Obviously, however, the relationship among the things classified must be a significant one. Consider the items in the following list for a moment:

Lead pencil
Lead, tetraethyl
Lead, Kindly Light

There is a point of similarity among the items in this list but it is difficult to imagine that it could be very significant!

Suggestions or "Rules" to Follow in Presenting a Classification

If a writer decides upon classification as an effective way of presenting a body of related facts, he needs to follow a number of "rules," all of them simply common-sense suggestions for clarity and meaningfulness. There are seven of them altogether.

1. *Make Clear What Is Being Classified.* Making clear what is being classified requires a definition of the subject if there is a question as to whether the reader will be familiar with it. For instance, "colloids" would need definition for some readers before a classification should be begun. Although a formal definition of a classifiable subject is rarely necessary in reports—the nature of the discussion will already have made it clear—remember that grouping the related members of a class will mean little to a reader who does not know what you are talking about in the first place.

2. *Choose (and State) a Significant, Useful Basis, or Guiding*

Principle, for the Classification. The basis of a classification governs it in that it dictates the nature of the groupings of members of a class. If we were to classify roses, for instance, according to color, each species in our listing would necessarily name a color. Color would be our basis. Thus we would list *red* roses, *pink* roses, *white* roses, and so on until we had named every different color found in rose blossoms.

It is possible to classify most subjects according to a number of different bases, some of them informatively significant, and some of them unimportant or of limited importance. Let's consider another example. A classification of draftsmen's pencils according to the color they are painted would be of no value at all, except perhaps to the aesthete who prefers a yellow to a blue pencil. Disregarding personal tastes about color, the draftsman would choose a pencil with lead of a desired hardness or softness. In short, a significant, informative classification could be made according to a basis of hardness or softness of lead, but not according to the color the encasing wood is painted. The basis should permit making a fundamental distinction among the members of a class.

A word or two about a commonly chosen basis for classifications: *use*. Everyone is familiar with numerous, practical classifications of objects according to the use to which they are put. A common example may be seen in the terms "sewing machine oil" and "motor oil." What we want to call your attention to is this: Classifications according to a basis of *use* are of limited value except for those who understand what the qualities are which make an object particularly suitable for a special use. In other words, the *real* basis for such a classification is not use at all; the real basis is the qualities or properties that make the various uses possible. To a person with any technical knowledge at all, the terms "sewing machine oil" and "motor oil" automatically suggest a possible real basis of the classification—viscosity. Before employing use as a basis for any classification, ask yourself two things: (1) Is *use* really what I want my reader to understand? Or (2) is the quality or property which distinguishes an object for a special use what I want my reader to understand? We do not mean to suggest that classifications should never be made according to a basis of use, for as a matter of fact, they may be very helpful. But you do not want to confuse the naming of a use with naming a quality or distinguishing characteristic.

Finally, we advise stating the basis, clearly and definitely, as a preliminary to naming members of a class. It is true, of course, that this rule need not always be followed; sometimes the basis is clearly implicit, as, for example, in the color classification of roses mentioned

earlier. But in general, it is a good plan to put the basis in words for the reader to see. The actual statement helps guarantee that your reader will understand you, and also helps you stick to the basis chosen.

3. *Take Care to Limit Yourself to One Basis at a Time in Listing Members of a Class.* Limiting yourself to one basis at a time is, of course, simply common sense. Failure to do so results in a mixed classification. This error results from carelessness either in thinking or in choice of words. The student who wrote, for instance, that engineers could be classified according to the kind of work they do as mechanical, civil, electrical, petroleum, chemical, and research was simply careless in thinking. A little thought would have suggested to him that research is not limited to any special branch of engineering. This error is obvious, especially once it is pointed out, but the other kind mentioned—improper choice of terms—is not so obvious. Just remember that the *names* of the members of the class should themselves make clear their logical relationship to the basis which suggests them. An author, in illogically listing fuels as "solid, gaseous, and automotive," may actually have been thinking correctly of "solid, gaseous, and liquid"; but, no matter what he was thinking, the term "automotive" was illogical. Still another practice to avoid is the listing of a specific variety instead of a proper species name, as listing fuels as gas, liquid, and *coal* (instead of "solid").

4. *Name All the Species According to a Given Basis.* In making this suggestion that every species be listed, we are simply advising you not to be guilty of an oversight, for as we pointed out earlier in this chapter, a writer would scarcely consider using classification as a method of presenting facts unless he has the facts to present. Just as important is the need for telling the reader what the limitations are upon the classification you are presenting, so that he will not expect more than it is your intention to give. A complete classification, or one without any limitations placed upon it, theoretically requires the listing of every known species; and sometimes species exist which it is not practical to list. A classification of steels according to method of manufacture, for instance, would not need to contain mention of those methods which were given up long ago. Limiting a classification is simply a matter of making clear what is being classified and for what purpose. Thus a classification of steels might begin, "Steels commonly in use today in the United States are made by . . . ," with the rest of the statement giving the methods of production. In this statement three limitations are made: steels made by

uncommon methods of production are neglected, steels made by methods of the past are omitted, and finally steels made in other parts of the world are ignored (though these latter might, of course, be made by methods originating in the United States).

5. *Make Sure That Each Species Is Separate and Distinct—That There Is No Overlapping.* The species of a classification must be mutually exclusive. This is clearly necessary, for the whole purpose of the classification is to list the *individual* members of a group or class; it would be misleading if each species listed were not separate and distinct from all the others. What usually happens when the error of overlapping species is made is this: the writer lists the same thing under a different name or, without realizing it, he shifts his basis. Classification of engineering reports as research, information, investigation, recommendation, and so on, illustrates this error, for it is perfectly obvious that no one of these necessarily excludes the others; that is, a research report may most certainly be an investigation report, or a recommendation report. To guard against this error, examine the listing of species you have made and ask yourself whether species A can substitute for species B or C or for any part of B or C. If so, you may be sure that you have overlapping species.

6. *Help Your Reader Understand the Distinction between Species.* When classification is being used as an expository technique, be careful to make your reader understand each individual species. Ensuring understanding may require that you discuss each species, giving a definition, description, or illustration of each—perhaps all three. In a discussion of steels an engineer might, according to a basis of the number of alloying elements, list binary, ternary, and quaternary alloys. He would then want to inform his readers, unless he was certain they already understood, what each of these terms means, what alloying elements are used, and what special qualities each steel possesses. What we are talking about here is not peculiar to classification writing: it is the same old story of developing your facts and ideas sufficiently so that your reader can thoroughly understand you.

7. *Make Certain That in a Subclassification (Where a Species Listed in Accordance with the Major Basis Becomes a Genus) You Deal with Differentiating Characteristics of But One Subdivision of Your Main Subject at a Time.* This is better illustrated than said. Suppose you had classified grinding wheels according to the nature of the bonding agent used in them as vitrified, silicate, and elastic and had then, in discussing elastic wheels, pointed out that they are further

distinguished by being made in several shapes, including saucer, ring, and so forth. Reflection will show that shape is not a distinguishing characteristic of elastic grinding wheels alone, but of all species, regardless of the nature of the bonding agent. It is clear, therefore, that while shape may be a suitable and useful basis for classifying grinding wheels, it is an unsuitable one for subclassifying elastic wheels. What is wanted for a thorough exploration of the subject of elastic wheels is a characteristic, or basis, peculiar to them and to none of the others. Thus you might subclassify elastic-bonded grinding wheels according to the specific elastic bonding material used, as shellac, Celluloid, and vulcanite. These would constitute subspecies which could not possibly appear under the heading of vitrified or silicate-bonded grinding wheels. In other words, you would have pointed out something significant about this particular kind of grinding wheel and not something characteristic of *any* grinding wheel.

Whenever you find yourself employing a basis for a subdivision which could be applied to the subject as a whole, you can either use it for the latter purpose, if you think it worth while, or incorporate the information into your prefatory discussion of the subject proper. An introduction to a discussion of grinding wheels, for instance, might very well contain the information that all kinds of grinding wheels, however made, come in various shapes.

When the process of subdividing a subject is followed to a logical end, a point comes when no further subdivision is possible. At this point one is dealing with varieties of a species. We might classify safety razor blades according to the number of cutting edges as single-edge and double-edge blades. In further discussion of single-edge blades we could point out that they are of two specific kinds, depending upon whether they have reinforced backs or not. Then we could say that the Gem blade is a variety of single-edge blade with a reinforced back and that the Enders and Schick are varieties of unreinforced single-edge blades. And that's about as far as we could go with our subdivision. We would have reached the end of the possibilities along that particular line of inquiry. Note that in discussing single-edge blades we used a principle for subdivision peculiar to single-edge blades alone—obviously double-edge blades could not have reinforced backs!

A Note on Partition

Earlier in this chapter we defined the term "partition"; now we should like to make some brief comments on the use of partition

in exposition. Classification, as we have seen, is a method of analysis (and exposition) which deals with plural subjects. You can classify houses, for instance, by considering them from the point of view of architectural style, principal material of construction, number of rooms, and so on. But you cannot classify *a house*, except in the sense of putting it into its proper place in a classification which deals with *houses*. You can analyze a particular house, however, by naming and discussing its component parts: foundation, floors, walls, and so on. This analytical treatment of a single thing (idea, mechanism, situation, substance, function) is called partition or, simply, analysis. As you know, it is a familiar and practical way of dealing with a subject.

The rules which we have discussed in connection with classification also apply to partitioning. Let's review the especially pertinent ones:

1. Any breakdown of a subject for purposes of discussion should be done in accordance with a consistent point of view, or basis, and this basis must be adhered to throughout any single phase of the discussion. Furthermore, it is imperative that this point of view be clear to the reader; if it is not unmistakably implicit in the listing of parts, it must be formally stated. You might, for instance, partition an engine in several ways: from the point of view of functional parts—carburetor, cylinder block, pistons, and so on; or from the point of view of the metals used in making it, such as steel, copper, aluminum. The importance of consistency in conducting such a breakdown is too obvious to need discussion.

2. Each part in the division must be distinctly a separate part: in other words, the parts must be mutually exclusive.

3. The partitioning must be complete, or its limitations clearly explained. It would be misleading to conduct an analytical breakdown of an engine which failed to name all of its functional parts. For special purposes, however, incompleteness could be justified by a limiting phrase, such as "the chief parts employed . . . ."

4. Ideally a subpartitioning of a part should be conducted according to a principle or a point of view exclusively pertinent to the part. It would be inefficient, for instance, to conduct an initial breakdown of a subject according to functional parts and then turn to a subpartitioning of one part according to metallic composition if all parts had the same composition. Besides being inefficient, for a general statement about composition could be made about all parts at once, such a subpartitioning would be misleading if the reader

were to get the idea that the metallic composition of the particular part under discussion *distinguished* it from other parts of the engine.

You do not need us to urge you to break down a subject for purposes of discussion; you would do it anyway, since it is a natural, almost inevitable, method of procedure. After all, a writer is forced into subdividing his subject matter for discussion because of the impossibility of discussing a number of things simultaneously. What we do want to urge is that you follow logical and effective principles in carrying out such divisions.

Conclusion

In conclusion, here is a restatement in practical terms of the fundamental ideas to keep in mind when you undertake to present information in the form of classification. These ideas will be stated as they would apply to the writing of an article of classification—such an article as is reprinted at the end of this chapter, on the subject of vat dyes; but don't forget that classification is a writing technique, not a type of report, and like all the writing techniques it must always be adapted to the context in which it happens to appear.

1. Devote your introduction to general discussion, including definition when necessary, of the genus which is to be classified. Anything you can say which will illuminate the subject as a whole is in order. It may be advisable to point out the particular value of classifying the subject, the limitations of the classification, a variety of possible bases for classifying the subject besides the one (or ones) which will be employed, and your own specific purpose. Be sure to state unequivocally what the basis is.

2. List the species, either informally or formally (as in the example on vat dyes), and then devote whatever amount of discussion you think is needed to clarify and differentiate the listed species. Subdivision of individual species, according to stated principles for division, may be carried out in the discussion.

3. Write a suitable conclusion (see Chapter 12).

ILLUSTRATIVE MATERIAL

The following illustration of classification as a special technique of exposition is intended to demonstrate how the technique found application in one technical report, rather than to serve as an ideal model. We suggest that you examine it to see to what extent it

lives up to the "rules" discussed in this chapter. Are departures from strict logical procedure justifiable?

Following the illustration of classification appears a brief example of partitioning.

Calco Vat Dyes*

Vat dyes are customarily divided into two groups, the Indigoid derivatives and the Anthraquinone derivatives. As a group, the Anthraquinone derivatives exhibit superior all-around fastness properties, generally are distinguished by excellent fastness to light, and have become the more popular group. A few Indigoid derivatives are outstanding in brilliancy of shade and this attribute, together with excellent fastness to washing and bleaching, counterbalance for many applications, the deficiency of poor fastness to light. Occasionally the lower cost of Indigoid dyes accounts for their use.

Vat dyes are insoluble in water. They are prepared for dyeing by "reducing" or "vatting" them in an alkaline reducing liquor which in commercial practice is usually a solution of caustic soda and sodium hydrosulfite. In this bath, vat dyes exist in the "leuco" state and exhibit definite affinity for textile fibers. When the fiber has absorbed this leuco dye, the dyed material is subjected to treatments which oxidize the leuco dye and neutralize the alkali, converting the dye back to a water insoluble, firmly fixed pigment. To develop the true shade and to produce a dyeing with maximum fastness properties, it is customary further to subject the dyed material to a final aftertreatment in a hot detergent bath.

Classification of Calco Vat Dyes

Since each individual Calco vat dye is a specific chemical compound, it is natural that a single set of reduction conditions and a single set of dyeing conditions cannot be specified for the entire group of vat dyes, nor even one set for the Indigoid and one set for the Anthraquinone groups. For practical purposes it has been feasible and customary to divide the entire range of vat dyes into four groups based on the dyeing conditions which yield the best strength and shade when cotton yarn skeins are dyed in a yarn to bath ratio of 1 to 20 by weight. The distinguishing factors between the first three groups are dyeing temperatures, caustic soda concentration, and the concentration of salt. The fourth group contains those dyes which require special treatment for the individual members.

As a general rule, it is advisable to use dyes from a single group when formulating compound shades. If the requirements of shade, fastness, or cost prevent the selection of dyes from a single group, they should be chosen from adjacent groups whenever possible. While this rough classification into four groups is useful to facilitate

* From "Applications and Properties of Vat Dyes," *Calco Technical Bulletin No. 802*, pp. 3–4. Reprinted by permission of the American Cyanamid Company.

Notice that these two paragraphs serve as an introduction and give one broad way of grouping dyes: according to chemical derivation. But this grouping, you will note, is not offered as a significant way of classifying vat dyes, at least not in so far as the purposes of this particular report are concerned.

Notice the care with which the basis of the classification is explained. What limitations on scientific accuracy are implied in this discussion?

the selection and application of vat dyes for many purposes, more explicit information is often of great value when formulating specific shades for application by a specific commercial method. Such data is tabulated in the section of this [report] entitled "Reduction and Dyeing Behavior of the Individual Vat Dyes."

Classification of Calco Vat Dyes According to Dyeing Behavior

Group	*Dyeing Temperature*	*Caustic Soda*: oz/gal	*Common Salt*: oz/gal
I	120° F. to 140° F.	0.25 to 1.50	None
II	100° F. to 120° F.	0.16 to 0.50	0.5 to 4.0
III	70° F. to 80° F.	0.16 to 0.50	1.0 to 8.0
IV	Dyes which require individual and special treatment		

Calco groups I, II, III, IV correspond to I.G. groups IN, IW, IK, and special stock vat methods.

In the last few years various improved batch methods and also several continuous methods of applying vat dyes have become available. Some of these use highly specialized machinery which subject the reduction and dyeing behavior of the vat dyes to exact control and frequently the ratio of fiber to bath is extremely low. Under such conditions the experienced vat dyer has greater latitude and it is possible to select dyes with greater emphasis on the factors of shade, fastness, and cost and with less regard for their group classification.

Divisions of the Report*

Reports are read by people in various positions and from different points of view. For the busy executive, interested only in the highlights of the investigation, a short, concise statement of the problem, the conclusions arrived at, and the recommendations, may be all that is necessary. The engineer, on the other hand, may require more detailed information. He may wish to know how tests were conducted, the instruments used and the analysis of the data compiled. To suit the needs of all it has been found best to divide and arrange the report as follows:

* Thomas O. Richards and Ralph A. Richardson, *Technical Writing* (Detroit, Mich., 1941), pp. 28–29. Reprinted by permission.

In this particular classification it is obviously impossible to contrive names for species which will adequately convey the significant information about them; hence species are given group numbers and the significant information is supplied in accompanying but separate columns. This method of presentation also eliminates, largely, the need for explanatory discussions of each species.

What is the effect of the discussion following the listing of species so far as the careful, informed reader is concerned?

This example of the use of partitioning is so obvious as to require scarcely any comment. Note that in this case, as with physical description and process description, the parts *in the partitioning are simply the parts of the thing discussed. A less exact partition might name: prefatory divisions, parts of the body of the report, and appended divisions.*

Foreword

The foreword or introduction defines the subject, scope, and purpose of the report. It may explain why the work was undertaken and upon whose authorization. Reference to other reports on the subject is desirable.

Conclusion

The conclusion of a report summarizes the results of tests made and records discoveries. The foreword and conclusion are the most difficult parts of the report to write. The foreword states the problem and the conclusion interprets the results. This interpretation should be written in such a manner that a reader less specialized than the writer has no difficulty in comprehending the report.

Recommendations

When recommendations are expressed they should be given emphasis by simple, forceful expression, by being set off on separate lines or paragraphs as the following:—We, therefore, recommend that:— We also recommend that: They should be placed under a separate heading "Recommendations."

Discussion

The discussion is the body of the report and contains the data collected during the investigation. These data may be tabulated or charted, and are usually explained and interpreted as the need requires. Whenever possible it is advisable to put the numerical test results under a separate heading:—Results of Tests.

Tables, Photographs, Drawings, and Curves

Tabulation of data, photographs, drawings, and curves are usually placed in the back of the report in the order named. However, the report should be arranged in such a manner that the information is easily available. This may require the inclusion of charts, drawings, etc., in the text. The method of assembling the report is left to the discretion of the author and the department head.

All material from which blue prints are to be made should be inked. Curves and drawings should have dates and names placed in the lower left hand corner if this is possible. The exception to this is where typed matter is to be blueprinted as is necessary where mathematical signs are used. In this case the typing is done on light onion skin paper using carbon paper placed backwards so as to make a carbon imprint on the back of the sheet.

General Data Required

Somewhere in the report detailed summaries of the following should be included:

Authorization for the work.

Description of apparatus with photographs or sketches signed and dated.

Conditions and method of test.

Description and illustration of mechanism under test.

Sample computations in design reports if these are involved.

Results and analysis of tests including curves and tabulated data.

Suggestions for Writing

In view of what we said in the discussion of classification, your first consideration in choosing a topic for a classification exercise should be your knowledge of the subject: do not attempt to write a classification of something you do not know well. Keeping this in mind, consider the following topics:

Measuring Instruments in Engineering (or some branch of engineering)
Grinding Wheels
Methods of Secondary Recovery of Petroleum
Vacuum Tubes
Architectural Drawing Instruments
Hammers
Home Refrigerators
Photographic Films
Insulators
Pumps

For Partition:

A Vacuum Tube
A Technical Magazine
A Poison Spray for Plants
An Engineer's Rule

9

Interpretation

Introduction

This chapter is concerned with what is popularly called analysis. People speak of analyzing a situation, or analyzing a problem. The word "analysis," however, has a special meaning to the rhetorician, for whom it is a general term covering the techniques of classification and partition, and for that reason we are going to use the word "interpretation" to mean what most people are probably accustomed to calling analysis. The rhetoricians get around this difficulty by making a distinction between formal analysis (as discussed earlier) and informal analysis (our present subject). It doesn't particularly matter what terminology we use so long as we are agreed on what we're talking about, and we'll consistently use "interpretation."

Interpretation, then, is the art of establishing a meaningful pattern of relationships among a group of facts, differing from formal analysis in that it does not attempt to be exhaustive, and in that it is freer of conventional form. It is nevertheless rigorously logical; and formal analysis naturally enters into interpretation rather frequently.

Interpretation is one of the most important aspects of science and engineering. Practical decisions such as where to drill an oil well, or what lightning protection system to use on a stretch of electric

power transmission line, are the result of interpretation of a body of facts; and so are Newton's laws of motion. Interpretation is a creative activity, requiring both knowledge and imagination. Sometimes the results of interpretation can be at best only tentative, as in long-range weather forecasting; sometimes the results are fairly certain, as in determining the cause of the failure of a particular gas engine; and there is an extreme in which the results are absolute, as in a mathematical equation where all the factors are exact quantities.

It is evident that from one point of view the study of interpretation is simply the study of logic, with mathematics as its most stable reference point. From another point of view, however, the study of interpretation is a study of the art of communication, of communicating to other people what you have found out through the application of logic to a certain group of facts. It is the latter point of view with which we shall be concerned in this chapter.

Three key questions arising in any interpretation are the following:

1. What is to be found out?
2. How was evidence obtained?
3. How will the interpretation be organized?

In addition to discussing these three questions, we shall comment on the place of the scientific attitude in the writing of interpretation.

What Is to Be Found Out?

The first job in making an interpretation is to decide what the purpose of the interpretation is. Similarly, the first job in writing up an interpretation is to tell the reader what it was you wanted to find out when you began the work. The exact problem must be clearly stated. Probably no single part of an interpretation is of more importance.

The major elements in a clear statement of a problem, or in an explanation to the reader of exactly what is (or was) to be found out, are the six following:

1. *Acquiring a Thorough Grasp of All the Available Information.* This step is, of course, a preliminary to the writing. It is only common sense to know all you can about a subject before writing anything about it. Sometimes, indeed, thorough knowledge will reveal that a supposed problem is only imaginary, as we discovered once when, after patiently trying to cure a certain plant of what appeared to be a disease attacking its leaves, we finally learned from a book that the leaves were just naturally supposed to look moth-eaten.

2. *Stating the Problem in Concise Form.* Although an expanded definition of a term may be several pages long, somewhere within that expanded definition there usually appears a single, formal, sentence definition. Similarly, in the statement of a problem there should usually be a single sentence in which the problem is formally expressed in its most basic form, even though the full explanation of what the problem is may require considerable space. We'll start with some remarks on this concise statement of the problem, with the understanding that the concise statement is only a part of the whole job.

Boiling a complex problem down to one short simple statement may prove a very keen test of your mastery of the subject. About the best insurance of success you can provide for yourself is to keep asking, "What am I really trying to do?" Try to avoid being dominated by conventional thinking and conventional phrases. Instead of saying, for instance, "The problem is to design a community center adequate for the needs of 3000 families," perhaps you might say, "The problem is to design a group of buildings in which 3000 families can conveniently secure food, clothing, furniture, hardware, drugs, automotive service, medical care, barber and beauty care, variety goods, and postal service." The second version is a good deal less concise than the first but much plainer. The term "adequate for the needs," from the first version, is given concrete meaning in the second.

Here is another illustration. If you are explaining the problem of designing a tank type of vacuum cleaner, instead of beginning with a discussion of nozzles, filters, exhaust areas, and so on, you might say that essentially the problem is to design a cylinder, open at both ends, in which dirt is filtered out of a stream of air drawn through at high velocity by a motor-driven propeller. In short, try to get to the very heart of the matter, eliminating for the moment all secondary considerations.

As always, however, the exact phrasing must be fitted to the reader. The statement of the problem of the vacuum cleaner given above would be more suitable for a layman than for an engineer who had been working on vacuum cleaner design for a long period of time.

3. *Defining Unfamiliar or Ambiguous Terms.* If your reader is to understand what you have to say about a problem he will surely have to understand all the words you use. If you can't avoid using words he doesn't already know, tell him what they mean.

4. *Distinguishing between the Primary Problem and Subordinate Problems.* A given problem usually turns out to be made up of a number of subordinate problems. When this is true, the relation-

ship between the primary problem and the individual subordinate problems must be shown. Each subordinate problem must be accurately stated, and its importance relative to the other subordinate problems indicated.

A simple illustration may be seen in the problem of choosing a new car. The primary problem here is of course the sum of numerous other problems: choice as to appearance, performance, economy, prestige, availability of maintenance services, and so forth. Many of us are good at persuading ourselves, with an assist from the advertisements, that the car we happen to want is the one that most nearly suits our needs; but this is not science. In a technical report, the subordinate problems would each be stated as precisely as possible, and an attempt would be made to evaluate the importance of each of them with respect to the purpose for which the car was intended. For a rural mail carrier, prestige would deserve attention only after such qualities as economy, body rigidity, and performance in mud had been considered. For a salesman, prestige might be more important.

One other fact should be noted here. If a problem is truly, in a given instance, the sum of a number of subordinate problems, then a statement of the major problem itself is accomplished partly through enumeration of the subordinate problems involved in it, in somewhat the manner illustrated above in reference to the choice of a car. So discussion of the primary and subordinate problems really serves two purposes: it provides a thorough statement of the primary problem, and it clarifies the relationships among the subordinate problems.

So far we have discussed (in addition to the idea of the need for thorough knowledge) three elements: stating the problem in concise form, defining unfamiliar or ambiguous terms, and presenting the subordinate problems. The following short statement of a problem will help to illustrate these elements.

> No one who lived through the period of design and construction of the Hanford plant is likely to forget the "canning" problem, i.e., the problem of sealing the uranium slugs in protective metal jackets. On periodic visits to Chicago the writer could roughly estimate the state of the canning problem by the atmosphere of gloom or joy to be found around the laboratory. It was definitely not a simple matter to find a sheath that would protect uranium from water corrosion, would keep fission products out of the water, and would not absorb too many neutrons. Yet the failure of a single can might conceivably require shutdown of an entire operating pile.*

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* Henry D. Smyth, *Atomic Energy for Military Purposes* (rev. ed.; Princeton, N. J., 1946), p. 146. Reprinted by permission of the author.

In this paragraph the last portion of the first sentence is a concise statement of the problem, and at the same time a definition of a bit of technical jargon. In the next to the last sentence, the major problem is divided up into subordinate problems. No comment is made on the relative importance of the various subordinate problems.

Perhaps it should be noted that the two major elements that remain to be discussed are in fact both concerned with the relation of the problem to background materials. Considering this relationship under two different headings will, however, serve a practical purpose.

5. *Distinguishing between What Is Already Known, and What Remains to Be Found Out, or Decided.* The reader will want to know why the investigation being reported was undertaken at all. If the subject concerned is one that has been investigated previously, one way of justifying the investigation, and of clearing the air in general, is to summarize the state of knowledge up to the point at which the investigation was begun, and to show what further information is desired. For instance, it has happened sometimes that the people of a certain community have engaged a firm of engineers to report on whether some civic improvement, like a power plant, should be undertaken, and then have fallen into dispute and hired a second firm to make another report. In the second report we should expect a very clear statement of what points have already been agreed upon, and then of what new information is being considered or of what additional factors are entering into recommendations.

6. *Giving Background Information.* A professional astronomer would need no explanation of the importance of designing an adequately rigid mounting bracket for a small astronomical telescope, but for a layman a little background information, prior to a discussion of a particular mounting, would be very helpful. He would readily understand that even a slight gust of wind might set up a minute vibration in a poorly supported instrument. And when it was pointed out to him that the resulting vibration of the image would be magnified by as many times as the telescope would magnify the image, the strictly engineering problem of the mounting would take on significance. The amount of background information necessary in any statement of a problem depends upon the reader's familiarity with the subject, but in case of doubt there is little question that some information should be given.

Finally, then, we come to the question of organizing the six elements that have been discussed. What is their proper order in the statement of a problem as a whole? The first, acquiring a thorough grasp of all the available information, can be eliminated at once since

it is not a part of the writing itself. The others we'll restate below prior to making some general remarks on organization.

I. Stating the problem in concise form.

II. Defining unfamiliar or ambiguous terms.

III. Distinguishing between primary and secondary issues.

IV. Distinguishing between what is already known and what remains to be found out, or decided.

V. Giving background information.

A controlling principle in regard to the organization is the question of explication versus synthesis. The problem may be stated near the beginning and then explained (explicated) bit by bit, or it may be stated only after considerable discussion, as the logical summation of the various subordinate factors entering into it (this would be synthesis). Usually the method of explication is more practical, but if there is any reason to feel that your reader may be hostile to your way of phrasing the basic problem, synthesis may be the better. You might imagine yourself telling a client that the problem is not whether his office building should be redecorated, but whether it should be torn down.

If the method of explication is used, the order of the list above may be about what you would want. For synthesis, the order would be approximately reversed. It must be clearly understood, however, that these remarks are no more than suggestions. There are too many variables involved in the process of stating a problem to permit any precise formula, or outline, to be written for use in all situations.

How Was Evidence Obtained?

An interpretation can be no better than the data on which it is based. Consequently, a second major part of an interpretation is the provision of any necessary explanation about how the data were obtained, or of a statement of their probable reliability. In a large tank of crude naphthalene there may be considerable random separation of naphthalene and water, and a sample taken at a given point might prove to be 100 per cent water. Any discussion of the contents of the tank would be useless unless carefully controlled sampling methods were used. And any reader should refuse to accept a statement about the contents of the tank which did not acquaint him with the method by which samples were taken, or at least with the probable accuracy of the results.

How Should the Main Part of the Interpretation Be Organized?

Having stated the problem, and possibly having commented on the source and validity of the data, the interpreter finds himself ready to explain the significance of all his evidence, and to state conclusions. He may have a great deal of evidence, and he may feel that, so far as getting his results down in writing is concerned, the situation is little short of chaotic. What he needs to do is to divide all his material into units and deal with one unit or factor at a time. Our immediate purpose is to discuss the problem of organizing the writing of the interpretation itself. This will involve consideration of how and where to take up the major factors to be discussed, and of how to present supporting data.

STATING AND ORGANIZING THE MAJOR FACTORS IN AN INTERPRETATION. Before explaining what "major factors" means, we should like to make a further qualification in the meaning of the term "interpretation." Previously, we said that interpretation is the art of establishing a meaningful pattern of relationships among a group of facts, differing from formal analysis in that it does not attempt to be exhaustive, and in that it is freer of conventional form. Now we should like to add the further qualification that this term (interpretation) is to be used only when the relationships among the facts being examined are not readily apparent. (If we ask which of five speedboats is the fastest, and then race them three times, and boat B wins every time, we don't need an interpreter to tell us which is the fastest.) The consequence of this added qualification is that the kind of problem we shall be considering from now on is the sum of a number of subordinate problems. Our purpose will be to make whatever generalizations are possible about organizing the interpretation of data concerned with complex problems.

The major factors involved in the organization of an interpretation are the subordinate problems, and standards of judgment. That is, a complex problem naturally breaks down into a number of subordinate problems which must be discussed one by one; and often (not always) a number of standards of judgment must be set up in order that an intelligent decision can be made.

Earlier in this chapter we pointed out the importance of identifying subordinate problems as a part of the statement of the major problem. That advice still holds, but now we are ready for a closer look at it. Frequently this question will arise: "Should I state each of the subordinate problems at some length as part of the statement of

the major problem, and only after they have all been stated fully start discussing the data related to them? Or should I state the subordinate problems very briefly as part of the statement of the major problem, and thereafter, taking each subordinate problem in turn, state it fully and discuss the data pertinent to it before going on to the next?"

Choice between these alternatives depends upon many circumstances, but the most important is probably the question of complexity. If there are so many subordinate problems that the reader wouldn't remember all of them, or if the problems are so complex that he wouldn't remember enough about them, they are certainly going to need careful statement as they come up in the body of the interpretation, regardless of what has been said about them earlier. Only a careful appraisal of the total situation can then determine how much should be said about them in the initial statement of the major problem. The shorter the report and the simpler the material, the less need there is for an elaborate initial statement.

Getting the subordinate problems into the best sequence as you organize the interpretation is sometimes difficult, but is often taken care of by natural relationships among the problems. Look for relationships like the following:

1. *Chronological.* "The first problem in checking the operation of the amplifier is the coupling of a load to its output . . . ."

2. *Spatial.* "The illumination of the desk will be analyzed with a lamp in five different positions . . . ."

3. *Cause and Effect.* "The concentration of these corrosive fumes in the surrounding atmosphere must be estimated before probable damage to structural members can be determined . . . ."

4. *Simple to Complex.* "The simpler aspects of the water supply problem—that is, the available sources and the pumping facilities—can be dealt with very briefly prior to considering the filtering and recycling of the water . . . ."

If you should decide that a very good organization is simply impossible, as when two problems appear to need discussion simultaneously, the best thing to do is to tell the reader your troubles when you start, and then write good transitions.

Before going on to consider how organization is affected by the introduction of standards of judgment, we had better give some attention to the meaning of this term. If you want to make an experimental determination of the pull of gravity at a particular spot on the earth's surface, you set up your apparatus and start measuring. It is true that there are subordinate problems involved, but the answer

sought is simply a number, with appropriate notation of the system of units used. No standards of judgment are needed. In contrast, we cannot very well recommend the purchase of a certain car without knowing beforehand the answer to the question, "For what?" What is the car supposed to do? (Nobody will ask what gravity is supposed to do.) In other words, in choosing a car we must proceed according to certain standards of judgment. And any discussion about which car to buy that is not set up in terms of a clearly defined set of standards of judgment will be pointless. This principle cannot be stated too strongly. Whenever you have a *judgment* to make, the principles or standards according to which you make it must absolutely be clearly stated, and must be restated as often as is necessary to show that the conclusions reached are in reasonable conformity to them.

Now let's list a few standards that are applicable to the choice of a car, and see what problems in organization develop. We shall assume that the car is to be used by a salesman, who does 90 per cent of his driving within a large city.

1. The price should fall within the medium range.
2. Operating costs should be low.
3. The performance should be good at low speeds.
4. The appearance should be good.
5. There should be a large trunk.

In addition, let's assume that a preliminary look at the market has shown that there are four makes or brands of car (A, B, C, and D) that should be considered.

Only a glance at the list of standards is needed to see that some of the standards will require considerable explanation. (What does "good appearance" mean? How do you know when operating costs get out of the "low" class—or how do you predict this for a new car?) With this need for explanation in mind, consider the following three ways of combining the major factors (the standards refer to the list above; the different kinds of cars are represented by capital letters).

Version 1

Statement of the problem
Explanation of all the standards
Explanation of why only four cars are to be considered
Judgment of each car in turn according to standard (1)
Judgment of each car in turn according to standard (2)
[Judgment according to standards (3), (4), and (5), same as above]
Summary of conclusions

Version 2

Statement of the problem
Listing of the standards (with very little explanation)
Explanation of why only four cars are to be considered
Explanation of standard (1), and judgment (according to this standard) of each car in turn
Explanation of standard (2), and judgment (according to this standard) of each car in turn
[Explanation of, and judgment according to, standards (3), (4), and (5), same as above]
Summary of conclusions

Version 3

Statement of the problem
Explanation of all the standards
Explanation of why only four cars are to be considered
Judgment of car A according to all five standards in turn
Judgment of car B according to all five standards in turn
[Judgment of cars C and D, same as above]
Summary of conclusions

All the possible combinations of major factors are not shown in the three versions above (for example, there might be a section or sections devoted to a general description of each of the cars, either near the beginning or later); however, the three versions do illustrate pretty clearly the kind of decision the interpreter has to make in organizing the major factors of a complex problem.

Which version is the best? For the car problem we would choose the second version. But for other applications it would be impossible to say which one is best without detailed knowledge of the whole situation. The chief point of these remarks, anyhow, is that if you are aware of the various possibilities, then you can select the most suitable organization for whatever subject and problem you have.

It should be remembered that the outlines above are by no means complete, being confined to illustrating relationships among the major factors. Later we shall illustrate a more nearly complete outline of an interpretation, but before doing so we shall make two additional comments about the major factors. These comments have to do with the elimination of possible choices, and with the handling of conclusions.

If it should happen that one of the four cars being considered in the foregoing problem appeared to be a most likely choice according to every standard but one, it might nevertheless be necessary to rule out the car on that one point. Suppose, for instance, that car C was excellent in respect to four of the five standards, but that it had an extremely small trunk. If the salesman couldn't carry his sam-

ples in the car it would be no buy for him. Once this fact had been shown, the car could be eliminated completely from any further consideration. This procedure speeds up and simplifies the whole interpretation. But a warning is needed here: Don't eliminate a possible choice on the basis of failure to meet a single standard if there is any chance that that possible choice (in our illustration, car C) would be the best one in spite of the one disadvantage.

A recurrent question in regard to conclusions is whether they should be stated in the body of the interpretation and then restated at the end, or whether they should be stated only at the end. The answer is that almost invariably they should be stated at both points. If, when the four cars are judged by standard (1), car B is found to be definitely superior to the others, a clear and rather formal statement of that conclusion will help to prepare the reader to accept whatever final conclusion is offered at the end of the interpretation. Of course where anything like an introductory summary is used the conclusions appear at the beginning as well.

In bringing to a close these remarks on organization of the major factors, we shall add a somewhat more detailed outline. The outline below indicates one way of organizing a discussion about the choice of a car: it is by no means the only way, and it is more generalized than would be desirable in practice, but it has the virtue of filling out the introductory portion more than do the three short versions presented earlier, and thereby of removing some possibly misleading implications of the earlier versions. Reference to Chapter 15, "Special Types of Report Organization" will illustrate differences in over-all organization that would be desired by certain companies.

I. Introduction

- A. Statement of the problem
  1. Discussion of the need for a recommendation
  2. Concise statement of the problem
  3. Concise statement of the standards of judgment
- B. Scope
  1. Statement of the cars to be considered
  2. Explanation of why the cars are restricted to the group named
- C. Comments on source and reliability of data
- D. Plan of development
  1. Comments on the presentation of data
  2. The over-all plan

II. Judgment according to the first standard

- A. Explanation of the standard
- B. Judgment of car A

    1. Presentation of data
    2. Interpretation of data
  C. Judgment of car B
    1. Presentation of data
    2. Interpretation of data
  D, E. —same as above

III, IV, V. —same as above for the remaining standards

VI. Summary of conclusions

PRESENTATION OF DATA. In addition to organizing the major factors just discussed, some decisions have to be made about the presentation of data. You're likely to commence writing an interpretative report with a thick pile of data at your elbow and questions like the following going around in your head: How much of this data should I put into the report? Where should I put it? What form should it be in? How much should I try to tell the reader about what it means, and how much should I assume he will see for himself?

The question of how much data to include must be answered according to circumstances. A college instructor often asks his students for all the raw data they took, and sometimes all the raw data are included in industrial and research reports. Unless it is quite clear that the raw data should be included, however, it is better to leave most of this material out. If it is put in, it should usually go into an appendix. Don't clutter up the text with it.

Whether or not all the raw data are put in, they must of course be sufficiently represented in the body of the interpretation to convince the reader that he understands the situation as a whole. And so we come to the question, "In what form should the data be introduced into the body of the interpretation?" The answer is—in any form at all. But remember, as the architects like to put it, that form follows function. If your purpose is to communicate, then whatever form will best convey your idea is the one to choose. Graphic aids provide a tremendous range of possibilities for the illustration or presentation of factual material, often in very dramatic form (see Chapter 20). In addition, there are such possibilities as presenting small samples of data, providing short lists of key figures or facts from the data, working out a typical or illustrative problem or calculation, summarizing trends in terms of range and percentage of change, and many others. Actually, however, the only special knowledge you need about the form in which data can be presented is an acquaintance with the basic concepts of graphic aids; other forms in which to present data will arise naturally out of the situation you are

discussing. (We refer here only to the writing problem. Knowledge of statistical methods and of technical methods of analysis in general is another matter entirely. There are some titles listed in the bibliography at the end of this book which are concerned with this subject.)

After he has decided upon the general organization of subordinate problems and (possibly) standards of judgment, the writer's principal tasks are to decide how much data to put in, where to put this material, what form to present it in, and how to reveal significant relationships without, on the one hand, confusing the reader with a mass of detail or, on the other hand, failing to offer sufficient supporting evidence.

Success in this last task of revealing significant relationships is made most certain by a very clear decision, before the writing is begun, as to what relationships should be explained. A carefully worked-out outline is of inestimable value. Start with the assumption that your reader is intelligent but uninformed; but then caution yourself that you cannot and should not discuss every detail.

There are three specific "don'ts" here that are of particular importance.

1. Don't put into writing the kind of information that is easier to grasp in the form of graphs or tables.

2. Having put some facts into tabular or graphic form, don't restate all the facts in writing. This is, according to our observation, a mistake students are especially likely to make.

3. Don't assume that, having made a table or a graph, *nothing* need be said about it. A little explanation of how to read the graph or table is often helpful. And almost invariably the significant relationships revealed by the table or graph should be pointed out.

These principles will be illustrated in the report at the end of this chapter.

Attitude

The attitude the interpreter brings to his writing should be the scientific attitude. This fact is perfectly self-evident, and yet it is not always easy to adhere to in practice. Detachment and objectivity are particularly difficult in the evaluation of evidence on an idea one has intuitively felt at the outset to be true, but which has come to look less certain as investigation progressed. We are all in some measure the creatures of our emotions. A counterbalance to the natural human desire for infallibility even in intuitions, however, is the deep emotional satisfaction of feeling above and in com-

mand of a given set of facts, with no obligation beyond saying that a given idea is true, or false, or uncertain. It is this emotional "set" that should be brought to problems of interpretation.

An illustration of the kind of attitude that should *not* be taken turned up in some student papers that we once read. We had given a class of engineers a sheet of data on the records of a number of football coaches and asked them to write an interpretation of the data. Personal loyalties evidently got mixed up in the analysis, for one student concluded solemnly that whatever the data might indicate, Coach X was definitely the best coach in the group because all the football players who had played under him said so!

Another problem of attitude that often arises in interpretation is that of adapting the manner of the interpretation to the individuality of a certain reader or readers. Human nature being what it is, novel or unexpected conclusions are almost certain to meet with opposition. A cool appraisal of probable opposition and an allowance for it in the manner of the presentation is not only wise and profitable; it is kind. Kind, that is, so long as the conclusion being offered is an honest one.

Summary

Interpretation, which is the art of informally establishing a meaningful pattern of relationships among a group of facts, has as its first important step the statement of the problem being investigated. Five elements that may enter into the statement of the problem are presenting the basic problem in concise form, defining unfamiliar terms, distinguishing between the primary problem and subordinate problems, distinguishing between what is known and what remains to be found out, and providing background information. The probable accuracy of the data concerned in the interpretation should be discussed. In organizing the body of the interpretation, the major factors are the subordinate problems and (where present) the standards of judgment. Supporting data should be put into graphic or tabular form wherever possible; the writing should be devoted to pointing out significant relationships. Where a choice is to be made among a number of possibilities, early elimination of some possibilities speeds up the whole process. Conclusions should be stated as they are reached in the body of the interpretation, even if they are to be summarized elsewhere. The attitude throughout should be impartial and objective, although not without a little human consideration of the individuality of the intended reader.

ILLUSTRATIVE MATERIAL

The report of the National Bureau of Standards that follows is devoted to an interpretation of data collected on storage conditions in libraries. The primary object of the report is to show what factors are important in the preservation of stored printed matter.

U.S. DEPARTMENT OF COMMERCE
Bureau of Standards

Miscellaneous Publications, Bureau of Standards: No. 128

A Survey of Storage Conditions in Libraries Relative to the Preservation of Records

BY
Arthur E. Kimberly
J. F. G. Hicks, Jr.

United States Government Printing Office
Washington, D.C.

A Survey of Storage Conditions in Libraries Relative to the Preservation of Records *[1]

By Arthur E. Kimberly[2] and J. F. G. Hicks, Jr.[2]

Abstract

A survey of leading present-day libraries was undertaken in order to determine the extent to which conditions of storage may be responsible for the deterioration of records and other material stored in libraries. The inspection stressed particularly conditions within the book stacks relative to the control of temperature, humidity, and air pollution, as well as the exclusion of light, all of which are recognized as important factors.

It was found that while the effects of light and dust were well guarded against in general, no library was able to control completely the variation of temperature and relative humidity within the narrow limits considered necessary for successful preservation of records and none attempted to minimize acidic pollutions of the air.

In view of the conditions found, as a result of this survey, and of corroborating laboratory experiments, optimum conditions of air purity, temperature, and illumination considered desirable for preservation of records were formulated, and means of obtaining them suggested.

Contents

I. External Deteriotating Agents

The permanence of paper is affected by two distinct groups of factors—one, the "internal" agents of deterioration or those substances produced or left within the paper by the method of manufacture; the other, the "external" agents of deterioration or the factors which are

* Miscellaneous Publication, Bureau of Standards, No. 128 (Washington, D.C.: United States Government Printing Office).

[1] This is one of a series of investigations concerning the preservation of written and printed records, which is being made at the National Bureau of Standards with the assistance of a fund granted for the purpose by the Carnegie Corporation to the National Research Council.

[2] Research associate, National Research Council.

The discussion begins with a definition of important terms: "internal" and "external" agents of deterioration. A concise statement of the problem follows immediately, in the last sentence of the first paragraph. The remainder of the first Roman numeral section is devoted

introduced by the conditions of use and storage of the finished paper. In order, therefore, to obtain some indication of the extent to which these external agents are responsible for the deterioration of books stored in libraries, a survey of storage conditions in present-day libraries was undertaken.

The preliminary step in such a survey was the definition of the external agents as set forth by the literature. As early as 1881, Girard[3] pointed out that cellulose, the principal constituent of paper, is readily attacked by acids and that the resulting product is further degenerated by contact with air. Later workers[4, 5] confirmed his statements and indicated other important factors in the deterioration of paper. Further perusal of the literature shows the following external agents to be of consequence in any consideration of paper preservation.

1. Light, [6, 7, 8, 9, 10, 11] particularly sunlight, attacks both the paper fibers and the sizing material, producing "yellowing" and brittling.

2. The adsorption of moisture containing sulphurous and sulphuric acids resulting from the combustion of coal and other present-day fuels, produces marked deterioration.[12, 13, 14, 15]

3. Successive changes in atmospheric temperature and relative humidity seem to exert a marked deteriorative effect,[16, 17] the phenomenon most frequently observed being that of brittling following prolonged storage in warm, dry places.

4. Insects, worms, molds, and fungi also attack books in some instances.[18, 19, 20, 21]

Since the literature indicates that the above factors influence paper preservation, it follows that the ideal library for the preservation of records would be one in which it is possible to control or eliminate

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[3] A. Girard, Ann. chim. phys., [5] *24*, p. 337; 1881.
[4] W. Herzberg, mitt, kgl. Materialprüfungsamt, Berlin Lichterfelde West., Jahrg. *25*, pp. 116–119; 1907.
[5] Aribert & Bouvier, La Papeterie, *42*, pp. 338–352; 386–392; 1920.
[6] V. Schoeller, Wochbl. Papierfabr., *43*, p. 3222 et seq.; (serial) 1912.
[7] P. Klemm, Papier Zt., *27*, pp. 961–963; 1902.
[8] C. Schwalbe, Wochbl. Papierfabr., *38*, pp. 1472–1473; 1907.
[9] B. Haas, Papierfabr., *12*, pp. 891 and 919; 1914.
[10] A. B. Hitchins, Paper, *22*, pp. 11–15; 1928.
[11] Kimberly and Hicks, B. S. Jour. Research, *6* (R. P. 307), May, 1931.
[12] Des Voeux & Owens, The Lancet, p. 47; Jan. 16, 1912.
[13] U. S. Bureau of Mines Bulletin No. 98; 1915.
[14] Mellon Institute, bulletins on smoke abatement (10 in all).
[15] Report, Chicago Assoc. Commerce, Smoke Abatement; 1915.
[16] O. Braums, Pulp Paper Mag. Can., *26*, pp. 11, 165; 1928.
[17] J. Norris, Library J., *38*, p. 16; 1913.
[18] W. R. Reinick, Am. J. Phar., *83*, p. 503; 1911.
[19] See Pierre, Compt. Rend., *164*, p. 230; 1917.
[20] V. Galippe, Compt. Rend., *169*, p. 814; 1919.
[21] Arturo Scarone, El libro y sus enemigos, Montevideo, 217 pp. 80; 1917.

to a statement of the subordinate problems: the group of four itemized external agents of damage.

the "external" deteriorating agents, and it was to this ideal library that the institutions investigated were compared.

II. Method of Inspection

Whenever possible the library in question was visited in order to discuss with the staff the general problem of paper preservation, as well as any difficulties peculiar to the individual library. Following this conference, a general tour of the library building was undertaken, particular stress being laid upon inspection of every phase of illumination and ventilation, including heating. The condition of the stored material and of the air surrounding it was also carefully noted. In the event that a visit proved to be impossible, the information desired was obtained as far as possible by correspondence.

III. Results

The results of the inspection of 13 libraries suggested by the New York Public Library are given in Table 1. The institutions included in the survey are located in the United States from the Atlantic coast to the Pacific coast and comprise both urban and country libraries.

In addition to the information obtained concerning air, light, and temperature control in the libraries visited, the following general observations of the condition of the material stored in these institutions were made, namely:

"Yellowing" was observed in hot, dry, and dusty places in the path of direct sunlight. Books stored in diffused light seemed to be little affected. "Brittling" was also observed under the same circumstances.

Dusty papers were frequently observed to be discolored and quite often brittle, but no general rule for the correlation of these facts could be formulated.

No damp places were observed at the time of this survey, but several spots were pointed out as being damp at other seasons. In these places, the papers examined seemed soft and "fuzzy," bearing a white powder which could readily be brushed off. They also show brown splotches known as "foxing."

Apparently, little difficulty was being experienced with pests, as is to be expected with the precautions taken to insure cleanliness and good ventilation.

IV. Discussion of Results

An inspection of Table 1 shows that of the 13 libraries listed only 4 possessed the equipment necessary for the removal of dust from the incoming air of their ventilating systems. Oil filters were used in 3 of the 4 libraries attempting dust removal. The elimination of dust from

In Section II, there is an explanation of how evidence was obtained.

The chief results of the investigation are presented in Table 1. Additional results, or evidence, are presented in textual form.

Section IV contains several good examples of the proper correlation of tables with text.

In this section, three of the four factors or subordinate problems listed at the end of Section I are discussed, but not in the order in

library air is very important, for dust particles, in addition to their abrasive action upon the paper and bindings of stored material, act as nuclei for the condensation of acidic moisture.[22] Every library inspected attempted to reduce the amount of dust in the stacks and on the books by systematic dusting. In several instances small hand vacuum cleaners were extensively used.

If air containing sulphur dioxide is allowed to come into contact with cotton fabric, sulphuric acid is formed upon the surface of the substance.[23] A similar reaction would be expected in the case of papers, since both substances are composed essentially of cellulose. This acid is not volatile at ordinary temperatures and, hence, exerts a cumulative effect throughout the life of the paper. If the paper contains iron, as most commercial papers do, the rate of formation of sulphuric acid from sulphur dioxide is greatly accelerated by the catalytic effect of the iron.[24, 25, 26] If this acid is once formed upon the sheet, its concentration varies with the moisture content (relative humidity) of the surrounding atmosphere, the acid acting as a dehydrator in a very dry atmosphere, literally burning the paper, while in a moist atmosphere it functions as an agent of acidic hydrolysis. The problem of air pollution is most serious as indicated by Table 2, which shows the precipitation of sulphuric acid in tons per square mile per year in several European and American cities. A further illustration of the quantity of sulphur dioxide present in the atmosphere is the fact that the sulphur content (determined as SO_3) of filter oil used in a New York public library increases about 100 per cent over the original value of 0.46 per cent SO_3 during three weeks' use in an oil filter. When one considers that oil filters are very inefficient as a means of removing acidic pollutants from the air this increase assumes a position of paramount importance as an index of conditions already at hand. Every indication of the situation at present points toward increasingly polluted urban atmospheres and in consequence an increased effect unless immediate steps are taken to minimize the amount of polluted air in libraries and similar institutions. It is believed that such a minimization could be effected by the substitution of a mildly alkaline solution for the water now used in humidifying and purifying library air.

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[22] Osborn Monnett, Smoke Abatement, U. S. Bureau of Mines Bull. No. 273.
[23] John B. Wilkie, U. S. Bureau of Standards, Research Paper No. 294.
[24] S. F. Cooke, Rôle of Certain Metallic Ions as Oxidation Catalysts, J. Biol. Chem., *10*, pp. 289–312; 1926.
[25] L. P. Wilson, Catalytic Action in the Oxidation of Cellulose, J. Soc. Chem. Ind., *39*, p. 177T; 1920.
[26] O. Baudisch and D. Davidson, Catalytic Oxidation by Means of Complex Iron Salts, J. Biol. Chem., *11*, p. 501; 1927.

which they were listed. The order of discussion is (1) adsorption of moisture . . . , (2) successive changes in atmospheric temperature and relative humidity . . . , (3) light. The fourth problem—insects, worms, molds, and fungi—is dismissed in a comment at the end of Section III. The organization would be considerably clearer if the order of discussion of the problems and the order of the original listing were the same. An even greater improvement would result from the addition of transitional material. The whole report is deficient in respect to transitions. The discussion of the individual problems, however, is clear and coherent.

The language in the last two sentences could certainly stand some simplifying.

Table 1.—*Survey of Conditions of Storage in Libraries*

Library	*Method of dust removal*	*Method of heating*	*Method of ventilation*	*Method of humidification of air*	*Kind of light in stacks*	METHOD OF COMBATING *Actinic rays of light*	METHOD OF COMBATING *Acidic pollution of air*
A [1]	Oil filter	Steam radiators	Direct fan system	Water spray	Sunlight and artificial	None	Oil filter and water spray
B [1]	Water curtain	do	do	Water curtain [2]	Very dull artificial	Dark stacks	Water curtain
C [1]	None	Hot air and steam radiators	do	None	Diffused daylight and dull artificial	Thick glass	None
D [1]	Not in use	Steam radiators	do	Not in use	Very dull artificial	Dark stacks	do.
E [1]	do	do	do	do	Diffused daylight and dull artificial.	Thick glass	do.
F [3]	None	Indirect steam	Fans; plenum chamber	None	Dull artificial	do	No information
G [3]	do	No information	Plenum chamber exhaust	do	No information	Art glass	None
H [3]	do	do	Windows	do	do	None	do.
I [1]	Oil filter	Steam radiators	Direct fan system	Water curtain	Very little diffused daylight and dull artificial	Thick glass	Oil filter and water curtain
J [3]	None; vacuum cleaner on shelves	do	No information	None	No information	Glass (ground and frosted)	None
K [1]	None	Indirect steam	Fans; steam chamber	Steam chamber	Dull artificial	Dark stacks	do.
L [3]	do	Windows	None	No information	No information	No information	do.
M [1]	Oil filter	Hot air	Direct fan system	Automatic humidifier	Dull artificial	Dark stacks	Oil filter

[1] Information obtained by inspection. [2] Temperature of water thermostatically regulated. [3] Information obtained by correspondence.

Consider how much space would be needed to present the data in Table 1 in text.

TABLE 2.—*Precipitation of sulphuric acid in cities*

City	Tons H_2SO_4 per square mile per year
Glasgow[1]	194.1
London[2]	180.2
Salt Lake City[1]	134.0
Manchester, England[3]	95.0
San Francisco[1]	83.1
Philadelphia[4]	83.1
Berlin[1]	16.2

Six of the thirteen libraries included in this survey possessed machinery for humidity control, but in two cases the apparatus was not in use at all, and in a third instance the plant was effective only in cool weather owing to the lack of a refrigerator. An attempt was made, several years ago, to use the third-mentioned plant in the summer, but when the advent of a spell of cooler weather precipitated the moisture from the air in the stacks upon the books stored therein, resulting in extensive damage from molding, the attempt was abandoned. All of the equipment in full-time use was of the water-curtain type with no means of regulating the temperature of the water save in one instance where modern thermostatic control had just been installed. The average library using average equipment cannot control the humidity of the air within its stacks very closely. Table 3 shows the variation of humidity in an institution which uses oil filters and a water spray for purifying and humidifying the incoming air.

TABLE 3.—*Variation of relative humidity within a library*

Day	Outside temperature	Outside humidity	Inside temperature	Inside humidity
	°F.	*Per cent*	*°F.*	*Per cent*
Feb. 24	50	42	59	38
Feb. 25	55	60	59	45
Mar. 5	40	57	60	30
Mar. 8	58	73	62	50

[1] Osborn Monnett, G. St.J. Parrott, H. W. Clark, Smoke Abatement Investigation at Salt Lake City, Utah, U. S. Bureau of Mines Bulletin No. 254.
[2] Des Vœux and Owens, The Sootfall of London, The Lancet, p. 47; Jan. 6, 1912.
[3] Recent Progress in Smoke Abatement and Fuel Technology in Manchester, Mellon Institute, Smoke Investigation Bulletin No. 10.
[4] Data from University of Pennsylvania.

Observe the makeup of these tables. See discussion of tables on page 344.

Inspection of Table 3 shows a pronounced fluctuation of relative humidity in this case, the lower limit of moisture content being below that considered desirable for the successful preservation of stored records. None of the libraries inspected made a definite attempt to reduce acidic pollution of the air, but those using oil filters and wate curtains reduced the acidity materially during the process of air treat ment for other purposes.

The situation regarding the protection of books from the action of daylight is considerably better than that dealing with the other phases of protection, for 10 of the 13 selected libraries minimize the effect of the actinic rays of light by the total elimination of windows in 3 cases, or by the use of thick glass in the remaining 7 examples. In only one instance is sunlight admitted freely to the stacks, and it may be noted that excessive deterioration is apparent in this case. Book stacks, in general, were found to be lighted by small, frosted incandescent bulbs which were switched on and off as required. This is a very commendable practice.

The results of the survey having shown the conditions which a book stored in an average library would encounter, a series of laboratory experiments was initiated to determine the extent of the effect of each individual "external" agent of paper deterioration and to ascertain means of minimizing its action.

Rosin and other materials used in the rosin sizing of paper have been subjected to the action of light with the result that all varieties of rosin, both bleached and unbleached, were found to be light sensitive, darkening in color under the influence of light.[27] The presence of ferrous iron was found to accelerate this color change materially. This is additional evidence that rosin sizing, as currently applied, is one cause of the yellowing of records with age. Furthermore, unpublished results obtained at the bureau by Rasch indicate that direct exposure of various types of record papers to sunlight, for a period of only 100 hours on each side, decreased their folding endurance from 25 to 63 per cent of the original. Both of these findings serve to emphasize the necessity of protecting records from the destructive effects of daylight. An investigation of the effect of air polluted with 5 to 10 parts sulphur dioxide per 1,000,000 on the various types of record papers is in progress, and results already obtained show that 10 days' exposure to such a polluted atmosphere causes losses in physical strength running as high as 40 per cent and increases in acidity ranging from 90 to 400 per cent. If so short an exposure as 10 days will produce an effect of this magnitude, one may well wonder that publications have survived as well as they have, and considering the constantly increasing acid pollution of the air, a long further life is problematic.

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[27] See footnote 11, p. 2.

The first sentence in the second paragraph after Table 3 is not strictly true. Compare the last sentence in Section III. The authors have forgotten that pest control is one of their problems of protection.

V. Recommendations

Taking into account present library conditions and the results of the laboratory work to date, the following recommendations as to library conditions may be made:

1. Daylight, particularly the actinic rays, should be rigorously excluded from bookstacks, either by the total elimination of windows or so far as possible by the use of thick glass. Any necessary illumination should be supplied by small, frosted, incandescent lamps, lighted as required.

2. Temperature and humidity should be automatically regulated within relatively narrow limits. A suggested range for temperature is 65° to 75°F., and for humidity, 45 to 55 per cent.

3. Incoming air should be purified to remove dust (oil filters) and acidic pollutants (alkaline-water wash in scrubbers).

4. When books or other records are stored in a purified atmosphere they should not be removed from it unnecessarily, as a short exposure to impure air may undo the preservative measures of many years' duration.

The machinery necessary to carry out recommendations 2 and 3 would be:

1. Oil filters of a type in which the oil coating is continually renewed.

2. Refrigerating apparatus to cool both incoming air (when necessary) and the solutions for the water curtains.

3. Water curtains, utilizing slightly alkaline solutions and having thermostatic control of temperature.

4. Apparatus to heat to desired temperature purified, cold air coming from water curtain.

In connection with air conditioning it is obvious that the installation and operation of costly apparatus is useless if members of the library staff and others are permitted to open windows, thereby allowing impure outside air free access to the library building. Some difficulty of this nature may be encountered at the outset, but if the operating conditions chosen are conducive to increased comfort, and it is believed that such is the case with the recommended conditions, these troubles should soon disappear. Conditioned air is coming to be used more extensively every day, not only in places of amusement but also in industrial plants and office buildings, with increased comfort and efficiency to all concerned.

VI. Summary

1. Daylight, polluted air, variation of temperature and humidity, and pests, are "external" agents of paper deterioration.

2. The effects of light are well recognized and guarded against

Note how easily the list of recommendations could be used as a set of standards of judgment if it were necessary to report on the quality of a given library as a storage place.

In conclusion, we would make the following general criticisms of this report: The statement of the primary problem and the subordinate problems is excellent. The presentation of data is well

in most libraries, although one library, ultramodern in most respects, is without protection against light.

3. No library of those inspected had taken all the precautions mentioned for protection against polluted air and variation of temperature and humidity.

4. Recommended storage conditions are those in which daylight and polluted air are excluded and the temperature and humidity maintained at 65° to 75° F., and 45 to 55 per cent, respectively.

VII. Acknowledgment

The assistance of the staffs of the libraries participating in this survey is gratefully acknowledged.

handled. The discussion of the individual problems is good. The organization is weak in the respects previously noted. Transitions are weak. There is very little introductory material; but this lack is partly offset by the abstract and table of contents. The style is too high falutin in spots. The summary is good.

Suggestions for Writing

A look at the files of *Consumer Reports* and *Consumers' Research* magazines will suggest numerous possibilities for interpretative reports. Various government agencies, such as the Civil Aeronautics Administration and the National Bureau of Standards, publish bulletins and reports containing analyses of technical problems. A good exercise is to read through an analytical or interpretative report, then copy out the data and write your own interpretation.

For a paper of around six hundred words, subjects like the following are practical:

1. How satisfactory is your fountain pen? Your alarm clock? Your brief case? Your set of golf clubs? (There are many other items of personal equipment that could be discussed.)

2. Within a certain area on the campus, are the concrete walks where they should be?

3. How well adapted for its purpose is the classroom you meet in?

4. How well does the registration system in your college work?

The following subjects are suitable for more extended discussion:

1. How well suited for safety and comfort are contemporary automobile body styles?

2. What attractions are there for a family of moderate means in owning a light airplane?

3. What are the relative advantages and disadvantages of a small sailboat in comparison to a small power boat for pleasure boating?

4. What are the relative advantages and disadvantages of engineering as a profession?

section three

Transitions, Introductions, and Conclusions

The duties of a writer are somewhat like those of a highway department. A highway department must know how to build a good road, a road that will carry weight. A writer, for his part, must know how to make a sentence that will carry meaning. Again, a highway department must know how to lay out a system of roads so that the traveler can go from one place to another with a reasonable expenditure of time and energy; he doesn't want to find that he must go through Kansas City to reach Chicago from New York. For the writer this is organization. Finally (for our comparison), the highway department must know how to devise and locate signs that will keep the traveler informed as to his whereabouts, and as to what lies behind him and what lies ahead. The writer's comparable duty is to write introductions, conclusions, and transitions. The purpose of this section is to discuss these last three elements.

Writing transitions, and to a lesser extent introductions and conclusions, is not a natural thing to do. It might be argued that it has little to do with the subject of the discussion; is a waste of time; might be taken by the reader as an insult to his intelligence. Unlike the organizing of a report and the writing of clear sentences, which are obviously important, the value of telling the reader what you are going to tell him needs learning, according to our observation.

In the following three chapters we shall offer some examples of writing in which there are clear transitions, introductions, and conclusions, and we shall make some suggestions about how to do such writing. We believe you will be persuaded that a route marker, in a report as on the highway, is a good thing.

10

Transitions

A transition is an indication of what is going to be said, a reference to what has already been said, or both. It may be a single word, a phrase, a sentence, a paragraph, or an even longer passage. In form, transitions may be quite mechanical and obvious, or unobtrusively woven into sentences with other purposes. We shall discuss what a transition is, how to write a transition, and where to place a transition.

What a Transition Is

We said a moment ago that a transition may be a word, a phrase, a sentence, a paragraph, or an even longer passage. Let's begin with words and phrases. Below are two passages which differ only in the presence or absence of transitional words.

> 1. Evidently the creation of a plutonium production plant of the required size was to be a major enterprise even without attempting to utilize the thermal energy liberated. By November 1942 most of the problems had been well defined and tentative solutions had been proposed. These problems will be discussed in some detail in the next chapter; we will mention them here.

> 2. Evidently the creation of a plutonium production plant of the required size was to be a major enterprise even without attempting to utilize the thermal energy liberated. Nevertheless, by November 1942 most of the problems had been well defined and tentative solutions had been proposed. Although these problems will be discussed in some detail in the next chapter, we will mention them here.*

The second version differs from the first only by the addition of two words ("nevertheless," and "although"), and yet it is noticeably smoother than the first. Careful reading of the two passages reveals very clearly the marked effect that two such apparently minor changes can create. Moreover, it should be noted that a definite change in meaning occurs, especially after "nevertheless." This word has the effect of adding force to the idea that it is remarkable that the accomplishments mentioned were achieved in so short a time.

There are numerous words and phrases that are frequently used as transitions in this manner. The following is a partial list:

however	in addition
on the other hand	indeed
in spite of	in fact
moreover	as previously noted
furthermore	in comparison
consequently	in the first place
also	secondly
now	finally
so	next
as a result of	then
therefore	in other words
of course	and
for example	but
besides	

Perhaps you will feel that such words and phrases as these do not exactly "indicate what is going to be said," as we claimed they do. Yet they do indicate, very often, the logic of the relationship between two units of thought. Such terms as "moreover," and "furthermore" indicate that "more of the same" is coming; "however" suggests that a different point of view is to be introduced or a refutation or qualification offered; "consequently" establishes a cause-and-effect relationship; and so on.

There is another way in which words and phrases serve a transitional purpose besides the one just described: that is through the repetition of key terms. Consider the italicized terms in the fol-

* From Henry D. Smyth, *Atomic Energy for Military Purposes* (rev. ed.; Princeton, N. J., 1946), p. 104. Reprinted by permission of the author.

lowing: "This experiment can be carried out successfully only under certain *conditions*. These *conditions* are . . . ." The second statement might have begun, "One of these . . . ," "The first of these . . . ," and so on. In this connection, it is a good idea to remember that repetition of the main subject of discussion itself helps keep the reader's eye on the ball, so to speak, and leads him from one thought to another. Suppose the above experiment were Millikan's oil-drop experiment: every now and then in a discussion of it, it would help to substitute "Millikan's experiment," or "the oil-drop experiment" for the term "experiment" or whatever other term might be used as the subject of sentences concerning it.

Sentence transitions and paragraph (or longer) transitions are associated less with stylistic qualities and more with organization than are the shorter ones just discussed. Usually these longer forms consist of a more or less plain statement of what has been or will be said. The last sentence in the passage quoted a moment ago is an example of a transitional sentence which is obvious in form. The first sentence of the present paragraph is an example of one less obvious in form. Both, however, serve the same purpose: to provide information about the content of a coming passage. This function may be seen again in the illustration below, which represents both the obvious and the less obvious forms.

1. Having considered the economic feasibility of this alloy as a transformer core, we turn now to the problem of hysteresis loss.
2. Even if this alloy is economically feasible as a transformer core, however, there still remains the problem of hysteresis loss.

This sentence, in either form, would serve as a good transition. The first of the two forms calls attention forcibly to the change of topic; the second performs the same function, but less obtrusively. The first might be the easier to remember; the second makes smoother reading. A choice between the two forms will follow consideration of this difference.

There is no important difference in principle between a sentence transition and a paragraph transition. In fact, our chief reason for using both of these terms was to make it perfectly clear that an entire paragraph, as well as a sentence, may be used to make a transition. Naturally, the same differences in form that may be found among sentence transitions hold true for paragraphs, as the following illustrations show.

1. In Chapter 1 and other early chapters we have given brief accounts of the fission process, pile operation, and chemical separation. We shall

> now review these topics from a somewhat different point of view before describing the plutonium production plants themselves.*
>
> 2. In previous chapters there have been references to the advantages of heavy water as a moderator. It is more effective than graphite in slowing down neutrons and it has a smaller neutron absorption than graphite. It is therefore possible to build a chain-reacting unit with uranium and heavy water and thereby to attain a considerably higher multiplication factor, k, and a smaller size than is possible with graphite. But one must have the heavy water.†

The second example is the less mechanical. In the original text it is followed by discussion of work done on heavy water—and thus it serves as a transition.

So far, we have considered some typical examples of transitions with special attention to their forms, ranging from single words to paragraphs, and from obvious, rather mechanical types to those which are less obtrusive. Finally, we should note the various purposes or functions that a transition may have. There are six important ones.

1. Smoothing out style, principally by indicating logical relationships through the use of single transitional words or short phrases. Example: "however," "on the other hand."

2. Indicating what topics are to be discussed. Example: "This section will be devoted to an analysis of the effect of temperature on bearing noise with a given lubricant."

3. Indicating what topics have been discussed. Example: "It is evident, then, that neither increasing the number of workmen nor increasing the speed of the line can, in the present circumstances, increase the output of Final Assembly."

4. Indicating a change of subject. Example: "In addition to the major advantages just described, the proposed changes in design would offer several secondary advantages."

5. Making reference to an earlier or later statement of a similar, related, or pertinent idea. Example: "As was said in the preceding section . . . ." "As will be shown in Chapter X . . . ."

6. Keeping attention focused by the repetition of key terms. Example: "The first step in aligning the circuit . . . ." "The next thing to do in aligning the circuit . . . ."

In conclusion we must say that the foregoing discussion has not by any means been an exhaustive statement of what a transition is. To go further, however, would be primarily to enlarge upon the theoretical rather than the practical aspects of the subject.

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* Smyth, *op. cit.*, p. 130.

† *Ibid.*, p. 147.

How to Learn to Write Transitions

On the subject of learning how to write transitions we have two practical suggestions to make, and that is all.

1. Don't hesitate to be quite mechanical about it at first. If you can't think of any better way, just say, "This concludes the discussion of so-and-so. Next thus-and-so will be discussed." As you continue to practice writing you will find that you acquire a habit of using transitions, and an ability to make them obvious or to conceal them as you wish. But don't expect the process to become completely automatic.

2. When you have completed a rough draft of a report, read through it once with the sole purpose of spotting points at which transitions should be added. After locating and marking all such points go back and write the transitions in. Possibly, also, you will want to delete some of the transitions that you originally wrote. It is possible to have too many, and it is possible to get them in the wrong place. This raises the question of how to decide where transitions should appear.

Where to Put Transitions

There is no formula according to which transitions can be located. Every report is unique, and presents its own problems. But if there is no formula there is a principle, and the principle is simply this: Don't give your reader a chance to get lost. Again, it's like putting up highway signs. In looking over your report for short transitions, it is wise to keep trying out the effect of adding a word or phrase to a sentence. This can be done quite deliberately. In checking the location of longer transitions it sometimes helps to start with the outline. Put an asterisk wherever there is enough shift in thought to seem to require a strong transition; then examine the text itself at the points noted.

A special problem that comes up here is the effect of the use of subheads, like the one above, on the handling of transitions. Clearly, the subhead is itself a transitional device, and can be expected to inform the reader fairly accurately of changes in subject. On the other hand, it is easy to overestimate the amount of attention a reader gives to subheads (see the comments on titles in Chapter 11, "Introductions"). On the whole our advice is to write the transition pretty much as if the subhead weren't there. And almost without exception our advice is to avoid using the subhead as an antecedent for a pronoun in the sentence that follows it. This point will be immediately

clear if you compare the following undesirable sentence with the one that actually appears under the subhead above ("Where to Put Transitions"): "There is no formula for this."

Illustration is probably more valuable than advice in respect to almost every aspect of the art of writing transitions, and so for the rest we shall turn to an extended illustration.

ILLUSTRATIVE MATERIAL

The illustrative material that follows consists of two paragraphs taken from Smyth's *Atomic Energy for Military Purposes.* These paragraphs can be regarded as fairly representative of good technical writing. They are not loaded down with transitions, but they do make clear, easy reading. Observe, however, the abuse of the word "such" in the second paragraph.

Transitional elements are in italics.

You will note that there are numerous pronouns (not in italics) which serve a transitional purpose. This is one of the problems we had in mind in our previous assertion that our discussion of transitions was by no means exhaustive. Even though often they are clearly transitional in function, it seems best to exclude pronouns from a consideration of transitions because their inclusion would add difficult theoretical problems without adding much of practical value.

The Equivalence of Mass and Energy

1.4. One conclusion that appeared rather early in the development of the theory of relativity was that the inertial mass of a moving body increased as its speed increased. This implied an *equivalence* between an increase in energy of motion of a body, that is, its kinetic energy, and an increase in its mass. To most practical physicists and engineers this appeared a mathematical fiction of no practical importance. Even Einstein could hardly have foreseen the present applications, *but* as early as 1905 he did clearly state that mass and energy were *equivalent* and suggested that proof of this *equivalence* might be found by the study of radioactive substances. He concluded that the amount of energy, E, *equivalent* to a mass, m, was given by the equation

$$E = mc^2$$

where c is the velocity of light. If this is stated in actual numbers, its startling character is apparent. It shows that one kilogram (2.2 pounds) of matter, if *converted* entirely into energy, would give 25 billion kilowatt hours of energy. This is *equal* to the energy that would be generated by the total electric power industry in the United States (as of 1939) running for approximately two months. Compare this fantastic figure with the 8.5 kilowatt hours of heat energy which may be produced by burning an *equal* amount of coal.

1.5. The extreme size of this *conversion* figure was interesting *in several respects. In the first place,* it explained why the *equivalence* of mass and energy was never observed in ordinary chemical combustion. We *now* believe that the heat given off in *such* a combustion has mass associated with it, *but* this mass is so small that it cannot be detected by the most sensitive balances available. (It is of the order of a few billionths of a gram per mole.) *In the second place,* it was made clear that no appreciable quantities of matter were being *converted* into energy in any familiar terrestrial processes, *since* no *such* large sources of energy were known. *Further,* the possibility of initiating or controlling such a *conversion* in any practical way seemed very remote. *Finally,* the very size of the *conversion* factor opened a magnificent field of speculation to philosophers, physicists, engineers, and comic-strip artists. For twenty-five years *such* speculation was unsupported by direct experimental evidence, but beginning about 1930 *such* evidence began to appear in rapidly increasing quantity. *Before discussing* SUCH *evidence and the practical partial conversion of matter into energy that is our main theme, we shall review the foundations of atomic and nuclear physics. General familiarity with the atomic nature of matter and with the existence of electrons is assumed. Our treatment will be little more than an outline which may be elaborated by reference to books such as Pollard and Davidson's* APPLIED NUCLEAR PHYSICS *and Stranathan's* THE "PARTICLES" OF MODERN PHYSICS.*

On page 200 is a diagram of the major transitions in Chapter VI, "The Metallurgical Project at Chicago in 1942," from Henry D. Smyth, *Atomic Energy for Military Purposes* (1946).

The arrows start at the point at which a transitional statement is made, and point to that part of the chapter (or elsewhere) to which reference is made.

The subheads which appear in the chapter are here written *above* the rectangle which represents the text to which they are related. The numerals within the rectangles are paragraph numbers. There are 47 paragraphs in the chapter.

The transitional statements represented here do not include those referring only to material within the same paragraph in which the statements appear, although there are, of course, many such transitions in the chapter. As an example of the kind of transition that is represented, paragraph 6.4 is quoted below in full.

6.4 In accordance with the general objectives just outlined, the initial objectives of the Metallurgical Laboratory were: first, to find a system using normal uranium in which a chain reaction would occur; second, to show that, if such a chain reaction did occur, it would be possible to separate plutonium chemically from the other material;

* Smyth, *op. cit.*, pp. 2–3.

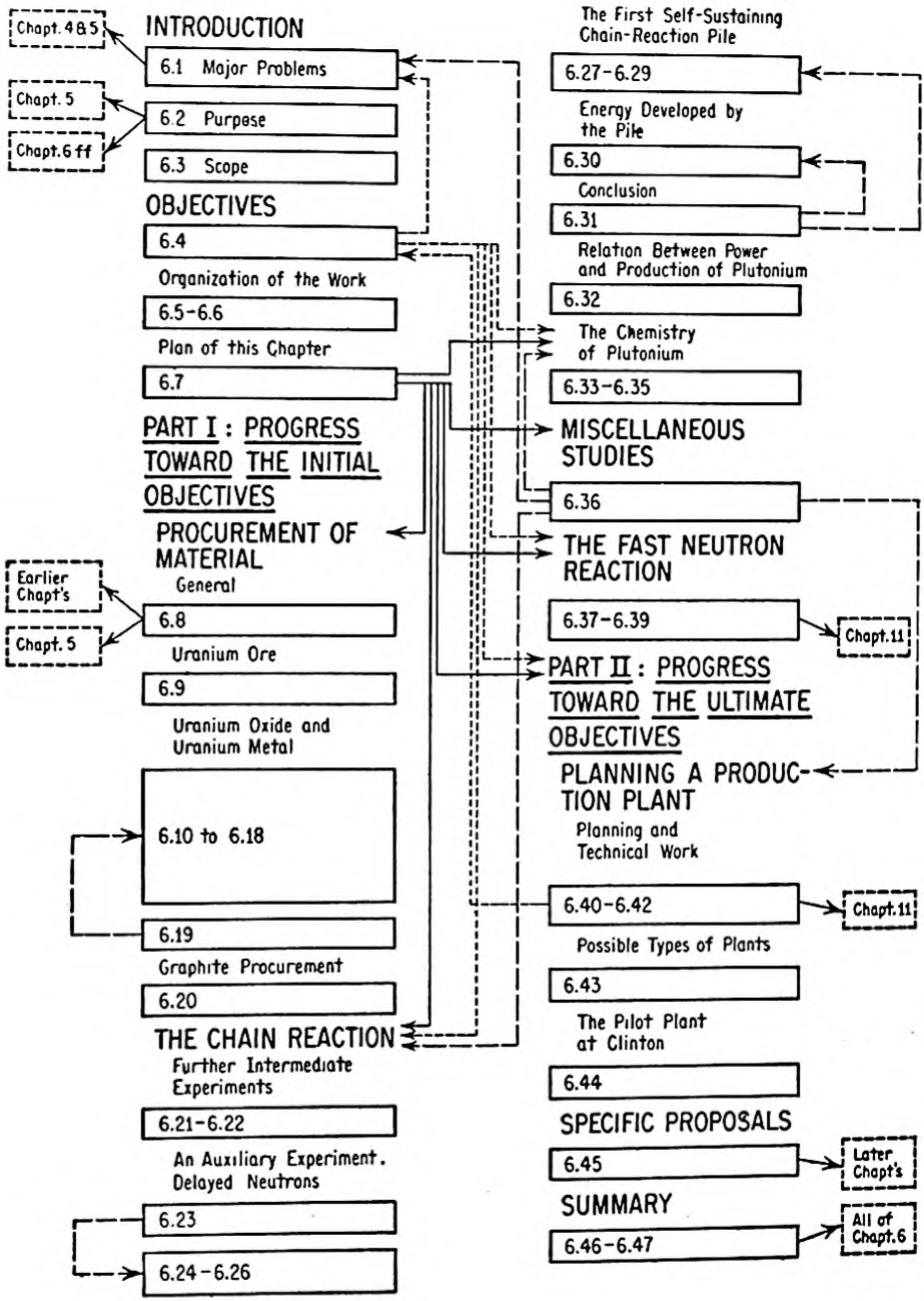

Diagram of Transitions.

and, finally, to obtain the theoretical and experimental data for effecting an explosive chain reaction either with U-235 or with plutonium. The ultimate objective of the laboratory was to prepare plans for the large-scale production of plutonium and for its use in bombs.*

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* Smyth, *op. cit.*, p. 89.

11

Introductions

The introductory portion of a technical report has several very definite functions. In fact, it is scarcely an exaggeration to say that the word "introduction" has a special meaning in technical writing, and that you might find it helpful to forget whatever meanings you have been accustomed to associate with the term. The introduction is, of course, the first portion of the text. It may or may not be preceded by a title page, letter of transmittal, preface, table of contents, list of illustrations, and abstract. Whether or not any or all of these elements are present, however, the introduction should be a complete and self-sufficient unit.

The primary purposes of an introduction to a technical report are to state the subject, the purpose, the scope, and the plan of development of the report. In addition, it is sometimes necessary to devote some space to explaining the value or importance of the subject.

The organization of the introduction and the degree to which any of its parts are developed depend upon circumstances. It should not be supposed that a good introduction is necessarily a long one; sometimes only a sentence or two is sufficient. The organization is

affected particularly by the need of stating a key idea in the opening sentence.

We shall discuss the four primary functions of an introduction in the order stated above, concluding with some comments upon the problems of initial emphasis and of the statement of the importance of the subject.

One important omission should be noted. In practice, introductions to technical reports often include a summary of the major conclusions or results that are presented in the body of the report. Since the presence of such a summary does not affect the fundamental character or functions of an introduction, no consideration of the introductory summary is contained in this chapter. A discussion of the introductory summary may be found in Chapter 4.

Statement of the Subject

At the very beginning, the reader should be given a clear understanding of what the exact subject of a report is. How this information is best presented depends, as usual, upon what the reader already knows. To some extent the title of a report is, or can be, a statement of the subject; but almost without exception the subject should be stated again in the introduction, and the title should never be used as an antecedent for a pronoun in the introduction. That is, if the title were "The Arc Welding Process," you should not begin the introduction with the words, "This process . . . ."

The effectiveness of the title of a technical report depends upon making it as informative as possible while still keeping it reasonably short. Titles which are merely ornamental, or even misleading, are a source of constant annoyance, as you have no doubt discovered when using periodical guides. Try to think of the title as it will appear to the reader. We recall once attending a university commencement in which one of the doctoral dissertations listed on the program was entitled, "The Life of an Excited Atom." From the titters provoked in the audience it was clear there were numbers of people present who, if not persuaded that this subject was risqué, considered it at least rather unnecessary. The title had fallen in with the wrong kind of reader, of course; or are we underestimating the physicist's sense of humor?

The statement of the subject in the introduction itself may involve one or more of the following three problems: definition of the subject, theory associated with the subject, and history of the subject.

It may prove necessary to define the subject, and also to define terms used in stating the subject. For example, in a discussion, in-

tended for an uninformed reader, entitled "Hydroponics—Gardens without Soil," we should want to explain both what the word "hydroponics" means, and what gardens without soil are. We might write, somewhere in the introduction,

> The word "hydroponics" is simply a name given to the process of growing plants in a liquid solution instead of in soil. Our chief interest will lie in the commercial application of this principle—that is, in "gardens" in which tanks filled with gravel and a mineral solution replace soil as the source of food for the growing plants.

In this illustration it is primarily the concept of soilless gardening which must be conveyed to the reader; but since that concept is expressed by the unfamiliar term "hydroponics," it is necessary to be certain that the relationship between the term and the subject is clear. In short, the writer should give special attention to making clear both the subject itself and any unfamiliar terms associated with it. If the subject is already familiar in some degree to the reader, the writer should adapt his statement of the subject accordingly.

Sometimes, however, even a well-written formal definition is insufficient, and it may become necessary to give the reader some background information. This background information is usually either theoretical or historical, or both.

In making large land surveys, it is occasionally desirable to stop the survey and re-establish the true north direction, in order to localize instrument errors. The new determination of true north may be accomplished by sighting on the pole star. For a student of surveying with no knowledge of taking astronomical "sights," a report on the procedures involved in establishing true north might well begin with a section on the theory of such an operation. Only through a comprehension of the theory could the operation itself (the principal subject) be fully understood. If such a section on theory were short, it could be included in the introduction proper; if it were long, it might better go into a section by itself, immediately following the introduction. In either case, the writer should remember that what he is trying to do is to make clear what the subject of his report is.

The purpose of discussing the history of a subject in a technical report is much the same as that of discussing the theory. It gives the reader an understanding of the total situation of which the particular subject is a part. For instance, in a report on the methods of manufacture of the "buckets" on a jet-engine turbine, a brief history of the development of the jet-engine turbine might help a good deal in showing why the buckets are now made as they are. A warning is in order here, however. Don't allow yourself to start discussing history

simply because you can't think of any other way to get started. Ask yourself if the history is clearly contributing toward the basic purpose of the report. If it is, good; if not, out with it.

Like the theory, the history can go either into the introduction proper or into a section by itself. In fact, theory and history are often combined—which is perfectly all right and natural.

Statement of Purpose

It is imperative that the reader understand the purpose of a report. And remember that we are concerned here with the purpose of the report, not of the subject. The purpose of a drill press is to drill holes; but the purpose of a report about a drill press might be to discuss the most efficient rate of penetration of the drill.

There can seldom be any objection to saying simply, "The purpose of this report is . . . ." Frequently the statement of both the subject and the purpose of a report can be accomplished in the same sentence, often the first sentence in the report. If the statement of the scope of the report, and of the plan of development of the report, can be included in this same sentence without awkwardness or lack of clarity, there is no reason for not putting them there. The fundamental requirement of a good introduction is that it perform the four basic functions; there can be no rules about how they are accomplished.

Statement of Scope

The term "scope" refers to the limits of a subject. The problem in the introduction is to explain what the limits are so that the reader will expect neither more nor less than he finds.

Limits may be stated in several ways. One way is concerned with the amount of detail: a report may be described as a general survey of a subject or a detailed study. Another way has to do with how great a range of subject matter is included. For example, a report on standardizing the location of the pilot's controls in aircraft might include all types of aircraft or only one type, like multi-engine aircraft. The reader must be informed as to what the range is. A third way is to note the point of view from which the report will be written. There is a good deal of difference, for instance, between announcing that a report is on the subject of the plumbing in a certain hotel, and announcing that the subject is the plumbing in this hotel from the point of view of a sanitation engineer.

These ideas may be of some value in helping you to think how to say what the scope of a given report is, but the basic idea to re-

member is simply that you must keep defining and qualifying your subject until it is certain that the reader will know what to expect.

Statement of Plan of Development

The statement of the plan of development of a report is simply a detailed application of the slogan, "First you tell the reader what you're going to tell him . . . ." It is a simple idea, easy to carry out, and unquestionably one of the most important elements in the introduction. The phrasing may be straightforward and formal: "This report will be divided into five major parts: (1) ————————, (2) ————————, ..." Or it may be more "literary": "The most important aspects of this subject are ————————, ————————, ————————, ..." The manner should be suited to the situation. Usually the statement of the plan of development comes at or near the end of the introduction.

Other Problems

Two other problems that should be mentioned are the need for a proper initial emphasis, and the occasional desirability of an explanation of the importance of a subject.

The first few statements made in an introduction are especially critical because on this very limited evidence the reader is forming an impression of the report as a whole. His impression as to the content and purpose of the report should be accurate; if he later finds that his first impression was wrong, confusion and irritation will be the probable result.

Ask yourself how much the reader already knows about this subject. Has he requested this particular report, or will it reach him unannounced? Is it concerned with a subject he is known to be interested in, or a project he is known to approve of, or is he likely to be, at the outset, indifferent or even hostile? In most instances there can be no objection to some variation of the "The purpose of this report . . ." beginning, but it would be a mistake to suppose that this is always true. Consider the following opening sentence:

> When it became apparent, in the fall of 19—, that the water supply of ———————— City would soon be inadequate to support the industry now located in the city, the City Council requested the firm of Smith and Rowe to prepare a preliminary report on the outlook for the immediate future, together with tentative recommendations of measures to be taken.

The initial emphasis here falls upon the urgent need for action. In comparison, an opening consisting of a statement of purpose would

be less effective; and an opening consisting of the first sentences of a history of the water supply problem might be quite misleading.

The importance of a failing water supply needs no explanation, but suppose the water supply was adequate, and a report was being written to show that steps should be taken to prevent a probable shortage only at the end of another ten years. The writer would face a quite different problem. He would have to devote considerable space to the task of proving that a merely probable event of ten years in the future was of immediate practical interest. Again, the fundamental principle is to analyze your reader and estimate his needs and attitudes. The last of the introductions quoted at the end of this chapter illustrates an extended comment on the importance or value of a subject.

Summary

The major functions of an introduction are to state the exact subject of the report, to state the exact purpose, to state the scope, and to state the plan of development. The statement of the subject is primarily a problem in definition but may involve extended discussion of background material, particularly of history or theory, or both. On the other hand, for an informed reader the subject need only be named. The statement of purpose is often combined with the statement of subject. The statement of the scope of the report may be conveniently considered in three aspects: the "range" of the subject matter, the detail in which the subject is to be discussed, and the point of view from which the subject is to be discussed. The statement of the plan of development presents no difficulties, but is extremely important; it normally appears at or near the end of the introduction. The organization of the whole introduction is affected by the selection of the proper initial emphasis. Sometimes it is desirable to explain the importance of a subject.

ILLUSTRATIVE MATERIAL

In the following pages four examples of introductions are presented. They range from a highly condensed one—the second—to a fully developed one—the fourth. The second particularly raises an interesting problem in psychology. The first and the fourth are the best of the group.

An Investigation of the Crash-Fire Problems in Transport Aircraft Fuel Tanks*

Introduction

The Technical Development and Evaluation Center of the Civil Aeronautics Administration is conducting a test program which has as its objective the development of aircraft fuel tanks with improved crash-resistant characteristics as compared to conventional types of fuel tanks now in common use.

The tests already completed in the preliminary portion of this program have been concerned with an investigation of the behavior of conventional types of fuel tanks during rapid deceleration and direct impact, and with securing basic data regarding fluid inertia pressures and structural loads encountered under typical crash conditions.

This report presents a general summary of the tests already completed, the broad deductions which can be reached from actual airplane crash experience and the results of detailed considerations which have been given to possible solutions to the problem.

In view of the nature of this report, many of its conclusions necessarily are tentative. It is to be expected that with accumulation of additional test experience, many basic concepts, and in particular the specific outline of test, may be changed. However, it is believed that at the present state of knowledge, the report will serve a useful and important purpose.

Evaluation of fuel tanks includes (in addition to estimation of their crash resistance) considerations of various practical features such as weight, efficiency of utilization of available wing volume, leakage and maintenance characteristics, complication of venting, measurement of fuel level and flotation efficiency. Although such practical features must be considered in the development of crash-resistant fuel cells, this report is concerned only with fuel-tank properties relating directly to the crash problem.

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* R. L. Field, Melvin F. Miller, and George L. Pigman, *An Investigation of the Crash-Fire Problems in Transport Aircraft Fuel Tanks*, Technical Development Report No. 134 (Indianapolis, Indiana: Civil Aeronautics Administration Technical Development and Evaluation, January, 1951), p. 1.

The first two paragraphs of this introduction are a statement of the subject of the report. The history of the subject is briefly indicated in the second paragraph. The initial emphasis (in the first paragraph) is good in one respect, a little weak in another. The subject and the basic problem are stated clearly, but not in such a way as to assure the reader that this is the exact subject with which this report is concerned. The uncertainty is heightened by the first words of the second paragraph, suggesting as they do that this report is going to be devoted to tests which were made after the preliminary portion of the program was completed. However, repetition of the words "already completed," in the third paragraph, eliminates any possibility of confusion.

The third paragraph is a good statement of purpose and of plan.

The fourth and fifth paragraphs are devoted to limitation of scope, and perform this function clearly. At the end of the fourth paragraph purpose is explicitly referred to, in relation to both the occasion and the importance of the subject.

Stability Study of 220-KV. Interconnection between Philadelphia Electric Company, Public Service Electric & Gas Co. of N. J., Pennsylvania Power & Light Co.*

The effects of line to ground short circuits on the stability of the interconnection have been investigated by careful mathematical calculation based on the best available data as to line and system characteristics. While, on account of unavoidable differences in actual and assumed conditions, and on account of the methods by which the problem has been simplified for purposes of calculation, extreme accuracy cannot be hoped for, nevertheless most of the essential factors have been considered and evaluated, and it is therefore felt that the final results obtained are substantially correct.

The report has been divided into three main sections as follows:

I Results
II Basis of Study
III Method of Calculation Employed
IV Representative Curves and Diagrams

* From a General Electric Company report, Engineering General Department (Schenectady, N.Y.), p. 1.

Measurement of Sound Levels Associated with Aircraft, Highway, and Railroad Traffic*

Introduction

The problem of noise levels created by aircraft in the vicinity of airports has become increasingly acute during the past several years The importance of this problem has grown with increasing number of private and commercial aircraft in use and, in particular, as a result of the establishment or expansion of airports in residential communities.

The complete solution of this problem ultimately must come through reduction of propeller and engine noises in aircraft, if all criticism of aircraft noise is to be avoided. Airplane and propeller

* R. L. Field, T. M. Edwards, Pell Kangas, and G. L. Pigman, *Measurement of Sound Levels Associated with Aircraft, Highway and Railroad Traffic*, Technical Development Report No. 68 (Indianapolis, Indiana: Civil Aeronautics Administration Technical Development Service, July, 1947), pp. 1–2.

This introduction gives the impression that it was written in haste, with no pleasure. It is certainly no pleasure to read. The second sentence would have a hard time getting by a freshman English teacher. And yet the introduction performs, at least to a limited degree, all of the four major functions of an introduction. The subject of the report is stated in the first sentence, and—for the technical reader for whom the report is obviously intended—the purpose is made fairly clear as well. The second sentence is concerned chiefly with scope. And the plan of the report is perfectly plain. (The little mix-up about how many main sections there are in the report will be found in the original.)

There are some engineers we know who would probably like this introduction. "Short and to the point," they would say, "except for that bad second sentence." Maybe so. We ourselves are a little dubious. We know some other engineers who might say that it's a sort of minimum good introduction. Not bad but not good either. Just mediocre.

Is the initial emphasis in this introduction good? The first few words of the first sentence state the general subject. This looks good. On the other hand, it is not until the end of the third paragraph that the exact subject is stated, after some slightly misleading cues have meanwhile been thrown in. And then the statement of the exact subject is ambiguous, because of the uncertain grammatical reference of "such" in the phrase "the results of such tests." (Notice the abuse of this word in the second paragraph also.) How could the first three paragraphs be improved?

manufacturers now are working toward this end in cooperation with private and governmental research organizations. However, until a solution is reached, and as an aid to such solution, a knowledge of sound levels actually existent in airport vicinities is urgently required.

During June, 1946 the Technical Development Service of the Civil Aeronautics Administration conducted sound level tests at a proposed airport at Malvern, Pennsylvania. These tests were not sufficiently complete for general application of the data obtained. In April, 1947 an additional test program was commenced to provide more complete and fundamental data. This report covers the results of such tests.

The purpose of the present tests was to determine sound levels in the vicinity of airports associated with particular aircraft, and comparative sound levels produced by highway and railway traffic. An additional purpose was to determine relative sound levels produced by various models of aircraft, and to obtain fundamental data which may be of incidental use in noise reduction design.

The presentation of sound level data in such form as to have technical significance, and at the same time to be understood readily by non-technical readers, is difficult. For clearer presentation there has been included in this report a section containing an elementary discussion of the properties of sound, methods of sound level measurements, and definition of terms. In addition, all final data are given in terms of relative loudness, which is believed to provide a simple and direct indication of the loudness of sound as heard by the average ear, related to a familiar and recognizable value.

Report on

The Direct Hydrogenation and Liquefaction of Coal*

I. Introduction

In recent years much time, money, and energy have been spent on the problem of obtaining synthetic liquid fuels. In European countries, where domestic supplies of crude oil are relatively very low, the production of synthetic liquid fuels has become imperative to their self-sufficiency. Today, even in the United States, where reserves of crude petroleum are seemingly very great, scientists are devoting great emphasis to the production of liquid fuels from other sources.

* From a report written by Mr. Don R. Moore while a student at The University of Texas, and reprinted here with his permission.

The statement of purpose in the fourth paragraph, although actually concerned with the tests, not with the report, does give a pretty good idea of what the report will try to discuss. It's a little awkward. Note that the first sentence in the paragraph is not literally true: the full purpose of the tests includes what appears in the second sentence as well.

The last paragraph contains comment on scope. On first reading, we somehow got the impression that it also gave some indication of plan of development, but upon reading the entire report we discovered that that was not true.

The initial emphasis of this introduction is upon the importance of the subject. The general subject is stated in the first sentence. The first three paragraphs of the report are devoted to the historical background of the subject.

Because of its great abundance and accessibility, one of the principal organic raw materials which has received consideration in recent years as an important source of synthetic liquid fuels has been coal. The known supply of coal in the world today is tremendously great compared to the known reserves of crude petroleum. Although new discoveries of petroleum have boosted supplies, there is little doubt that the supply of petroleum in the United States will run short many, many years—even centuries—before coal supplies are exhausted. Scientific estimates have placed the life of petroleum reserves in the United States at between ten and fifty years while estimates have placed the life of coal reserves well in excess of one thousand years.[1]

It is because of this possibility of an impending shortage of crude petroleum that the conversion of coal to oil by hydrogenation processes has become so important. As yet, the production of fuel oils from coal is not economically feasible in the United States. Gasoline produced from the direct hydrogenation of coal would cost 22.6 cents per gallon if produced by a plant which had a daily production of 3000 barrels or between 15 and 16 cents per gallon if produced by a plant which had a daily production of 30,000 barrels; the same fuel produced from crude petroleum by the common thermal cracking refinery process would cost 8.5 cents per gallon.[2] However, in the future it is believed that engineering achievements in the field of coal-hydrogenation coupled with a rise in the price of fuel oils produced from crude petroleum (which will surely occur should a shortage of crude petroleum arise) will possibly make the production of gasoline and other motor fuels from coal-hydrogenation economically feasible.

Although this conversion of coal to oil appears to be a mysterious and complicated process, it may be discovered from the discussion appearing in the second section of this report that the composition of certain bituminous coals which have been freed from ash resembles the composition of crude petroleum to a great extent.

The actual chemical conversion of coal to oil can be accomplished by either of two hydrogenation processes—the direct, or Bergius,[3] process or the indirect Fischer-Tropsch[4] process. The material presented in this report, however, will concern only the primary reaction involved in the conversion of coal to oil by the direct hydro-

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[1] *Synthetic Liquid Fuels,* Hearings before a Subcommittee of the Committee on Public Lands and Surveys, United States Senate, Seventy-eighth Congress, p. 137.

[2] *Ibid.*, p. 53.

[3] The Bergius Process (named after a German who was a pioneer in the field of coal-hydrogenation) is a process in which hydrogen is forced into the reactive intermediates formed by a thermal decomposition of the complex molecular structure of the coal.

[4] The Fischer-Tropsch Process, devised by the two German scientists, is a process in which the coal is burned to form "water-gas" which is then hydrogenated to form oils.

This paragraph and part of the next are concerned with theoretical background.

Here the scope of the report is limited. The sentence beginning, "The material presented . . ." limits what we earlier called the range of the subject. In the next sentence point of view and detail are mentioned.

genation process. This report will discuss the conversion from a chemical aspect and will not cover engineering details and difficulties involved in such a conversion by commercial-scale continuous-phase[5] processes.

It is the purpose of this report to discuss the mechanism and yields of the primary reaction involved in the synthesis of coal to oil by the direct hydrogenation process, the operating variables involved in the reaction, and the effect of the rank and type of different samples of coal upon the total liquefaction yields from the reaction. These topics will be discussed in the order stated.

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[5] A continuous production process in which coal is constantly fed to a liquefaction converter and in which the liquefaction yields are constantly removed for further hydrogenation.

The introduction concludes with a formal statement of purpose and plan.

The subject is clarified by definition of terms.

12

Conclusions and Summaries

As an introduction is, by definition, the beginning of a report, so is the conclusion or summary the end. In this chapter we shall discuss the chief considerations involved in bringing a report, or a section of a long report, to an end.

One of these considerations is, of course, an aesthetic one: how to give a sense of finality and completeness to the discussion. We shall have some comments to make on this problem, but for the most part we shall be concerned with the content, rather than with the possible aesthetic function, of the conclusion or summary. First we shall discuss conclusions, from two different points of view, and then summaries.

We've been using these two words, "conclusion" and "summary," together so far, and it may have seemed that one or the other alone would do as well. The reason for our sticking rather awkwardly to both is that we want to use them in different and rather specialized ways. That is, a conclusion, in this chapter, is not going to mean the same thing as a summary.

In reference to the end of a piece of writing, the word "conclusion" is somewhat ambiguous. It is sometimes used to mean roughly "the end," and sometimes to mean "decisions reached," or "findings."

If a conclusion is essentially simply "the end," its function is primarily aesthetic, to bring the discussion smoothly to a stop. This need is felt particularly when there seems to be little point in reviewing what has been said, and yet it seems awkward just to stop. *Often it is wise just to stop;* but not always. For instance, at the end of a description of how to develop film at home you might want to conclude: "Although, as has been shown, developing and printing film is not a difficult process, it is one which affords a great opportunity for experimentation with effects, and thus provides a continuing novelty and challenge. Reasonable caution in carrying out the steps just described will start you on the way to a most pleasant and interesting hobby." Nothing significant in the way of review or of decisions has been said here, but a reasonably graceful "aesthetic" conclusion has been made.

A report in which decisions are to be reached, or "findings" are to be stated, presents an entirely different problem. Here the conclusion, or conclusions, are the end point in an argument, or an analysis. The conclusion should be impressed on the reader's mind as forcibly as possible in the last paragraph or section (of course this doesn't mean that you should argue more strongly for the decision than the evidence warrants). In a short report the decision or decisions, or findings (often called "results") may appear only at the end; and also in a long report devoted to reaching only one important decision, that decision may appear only at the end. On the other hand, there may be a series of decisions which are restated at the end, sometimes formally entitled "Summary of Conclusions." The following paragraph is an illustration of this type of conclusion.

Conclusions

Based on the work conducted on the hydraulic unit at this laboratory and reported herein, it is concluded that:

1. The oil in the system under normal operating conditions contained small amounts of air.

2. The amount of air in the oil varied considerably with different operating conditions.

3. There appeared to be no significant difference in the operation of the unit from a force vs. speed standpoint when operated with varying amounts of air in the oil.

4. Excess air introduced into the oil through the pump intake readily dissolved in the oil when it was subjected to high pressures so that there appeared to be no air mechanically entrained in the oil during normal operation of the unit.

5. The greater efficiency reported for this hydraulic machine is probably due to the fact that it is operated with forces nearer the actual cutting force so that the system is always fairly near equilibrium, thus always placing the maximum load on the cutter, but never overloading it.

6. There appeared to be no significant difference in the operation of this unit when using either Oil A or Oil A (R & O).

It is not necessary to number the conclusions, although in this instance it was surely a good idea.

Finally, there are the summaries. A summary is, as we have already implied, a review or concise restatement of the principal points made in the discussion. It is obviously more useful at the end of a report engaged chiefly in presenting a body of information than in an analytical or argumentative report, or in a descriptive report which would not justify anything more than an aesthetic conclusion.

The writing of a good summary requires a very clear grasp of each one of the fundamental ideas of the report. In fact, writing a summary may serve as a test of whether you have actually seen and formulated clearly the fundamental ideas involved in the report. A comparison of the introduction and the summary should reveal no inconsistencies, and of course the major sections in the report should all be represented in the summary.

The following illustration contains not only a summary but the paragraph which immediately precedes the summary. The purpose of including this extra paragraph is to show how it is summarized in the last sentence of the Summary.

Cooperation between the Metallurgical Laboratory and du Pont

Since du Pont was the design and construction organization and the Metallurgical Laboratory was the research organization, it was obvious that close cooperation was essential. Not only did du Pont need answers to specific questions, but they could benefit by criticism and suggestions on the many points where the Metallurgical group was especially well informed. Similarly, the Metallurgical group could profit by the knowledge of du Pont on many technical questions of design, construction, and operation. To promote this kind of cooperation du Pont stationed one of their physicists, J. B. Miles, at Chicago, and had many other du Pont men, particularly C. H. Greenewalt, spend much of their time at Chicago. Miles and Greenewalt regularly attended meetings of the Laboratory Council. There was no similar

reciprocal arrangement although many members of the laboratory visited Wilmington informally. In addition, J. A. Wheeler was transferred from Chicago to Wilmington and became a member of the du Pont staff. There was, of course, constant exchange of reports and letters, and conferences were held frequently between Compton and R. Williams of du Pont. Whitaker spent much of his time at Wilmington during the period when the Clinton plant was being designed and constructed.

Summary

By January 1943, the decision had been made to build a plutonium production plant with a large capacity. This meant a pile developing thousands of kilowatts and a chemical separation plant to extract the product. The du Pont Company was to design, construct, and operate the plant; the Metallurgical Laboratory was to do the necessary research. A site was chosen on the Columbia River at Hanford, Washington. A tentative decision to build a helium-cooled plant was reversed in favor of water-cooling. The principal problems were those involving lattice design, loading and unloading, choice of materials particularly with reference to corrosion and radiation, water supply, controls and instrumentation, health hazards, chemical separation process, and design of the separation plant. Plans were made for the necessary fundamental and technical research and for the training of operators. Arrangements were made for liaison between du Pont and the Metallurgical Laboratory.* [NOTE: this last sentence summarizes the preceding paragraph.]

As you will have observed, the style of this summary is distinctly "choppy." One bald statement follows another. This is probably a good idea. The summary can be regarded almost as a list of the major ideas, and there is little reason to try to escape very far from the form of a list. Indeed, summaries are sometimes broken down into numbered statements, as was the "conclusion" quoted earlier.

Finally, three general remarks. In the first place, we must say plainly that conclusions and summaries cannot be written by formula. The principles we have discussed are of considerable value, but they are only principles, not prescriptions. We said, for instance, that the conclusion comes at the end of the report. But this is not always true. Not infrequently conclusions are presented near the beginning of the report. And sometimes they come near, but not at, the end; perhaps a paragraph on plans for future work appears at the end, following a "conclusions" paragraph. As always, the important thing is the successful accomplishment of the function itself, not the particular method adopted. In the second place, we should like to put forward a warning: Don't insert new material into the conclusion itself (as distinguished from another paragraph on another subject).

* Smyth, *Atomic Energy for Military Purposes*, pp. 128–129.

This practice can be very confusing. In the third place, remember that a relatively long summary is a contradiction in terms. Keep it short.

Summary

For convenience, the final section of a report can be classified as either of two types: conclusions or summaries. Conclusions can be subdivided into two kinds: aesthetic and "decision." An aesthetic conclusion brings the report to a graceful close without attempting to restate any significant information. A "decision" conclusion restates a decision (or decisions) which has been reached in the text, or sometimes presents the decision for the first and only time. A summary is a restatement of important information. The conclusion or summary normally, but not invariably, appears at the end of the report. It should contain no new ideas, and it should be relatively short.

section four

Types of Reports

So far we have been concerned with various fundamental skills and techniques needed in technical writing. It is time we turn our attention to forms of writing in which these skills and techniques are combined—that is, essentially, to reports.

In some organizations there is little formality attached to report writing. Each writer decides what form is best suited to what he has to say. Elsewhere, particularly in large organizations, numerous and sometimes elaborate forms are devised and given names; and thereafter, within the organization, these forms are spoken of as types of reports, and young men are given instructions on how to write them. This is exactly as it should be, provided the forms devised satisfy the needs of the organization. But it does result in the creation of a tremendous lot of "types." In a casual search that took no more than thirty minutes we once turned up the following examples of so-called types of reports:

preliminary	*service*	*examination*
partial	*operation*	*examination-trip*
interim	*construction*	*inspection*
final	*design*	*investigation*
completion	*failure*	*memorandum*
status	*student-laboratory*	*notebook*
experimental	*industrial-research*	*short-form*
special	*industrial shop*	*periodic*
trade	*evaluative*	*information*
formal	*test*	*work*

It is possible that the foregoing list could be boiled down to a few fundamental types. No one, however, has ever succeeded in winning general acceptance of a working system of classification of reports, and it seems unlikely that any attempt will ever succeed. Your best preparation for writing whatever sort of report you may be asked for is (1) a mastery of the fundamental techniques and skills of technical writing, and (2) an acquaintance with some widely used types of reports, so that the word "report" will have concrete meaning for you. Of course a fairly wide variety of reports, or excerpts from reports, has already been presented as illustrative material in earlier portions of this book.

The purpose of the following chapters is to introduce, in some detail, a few generally accepted types of reports, and in addition to take up some composite forms which, although not precisely reports, can conveniently be considered at this point. All of the forms discussed have in common the fact that in them the special techniques described earlier appear in combination. The reports discussed are the progress report, the recommendation report, and what we shall here identify loosely as the form report. Subsequent chapters will be devoted to oral reports, business letters, and writing for professional journals.*

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* *For a more detailed discussion of report classification see A. C. Howell,* A Handbook of English in Engineering Usage *(New York, 1940), and L. A. Rose, B. B. Bennett, and E. F. Heater,* Engineering Reports *(New York, 1950).*

13

The Progress Report

Introduction

One easily distinguishable type of report is the progress report—distinguishable because of its purpose and general pattern of organization. This chapter explains how to prepare a progress report.

The progress report has as its main object the presenting of information about work done on a particular project during a particular period of time. It is never a report on a completed project; in some ways it is like an installment of a continued story. Progress reports are written for those who need to keep in touch with what is going on. For instance, executives or administrative officials must keep informed about various projects under their supervision in order to make intelligent decisions as to whether the work should be continued, given new direction or emphasis, or discontinued. It may be that the report will serve only to assure those in charge of the work that satisfactory progress is being made—that the workers are earning their keep. Not the least important function of the progress report is its value as a record for future reference.

It is neither possible nor worth while to list here the extent of the activities on which progress reports are made. The extent is, of course, tremendous. Any kind of continuing, supervised activity may have progress reports made on it—anything from research projects in the field of pure science to routine construction jobs. Nor is it possible to be dogmatic about the frequency with which such reports appear: often progress reports are made on a monthly basis, but sometimes the week may be the time unit, or the quarter-year. Anyhow, the time covered in the report has little to do with the way the report is organized and presented.

Organization and Development

About the best way of getting at the problem of what should go into a progress report, and how, is for the writer to ask himself what the reader will want to find in the report.

Common sense tells us that the reader will want to know at least three things: (1) what the report is about, (2) what precisely has been done in the period covered, and (3) what the plans are for the immediate future. Quite naturally, he will want this information given in terms he can readily understand, and he will expect it to be accurate, complete, and brief. Great emphasis is often placed on brevity.

The foregoing analysis suggests a pattern of organization as well as some clues regarding development of the report. From the standpoint of organization, there should be three main sections: a "transitional" introduction, a section giving complete details of progress made during the current period, and a "prophetic" conclusion.

The Transitional Introduction. In the first of these sections, the transitional introduction, the reporter must identify the nature and scope of the subject matter of his report, and he must relate it to the previous report or reports. He may be expected to provide a brief summary of earlier progress to serve as a background for the present account of progress. Finally, if the circumstances seem to warrant—or it is expected of him—he may present a brief statement of the conclusions reached in the present unit of work, along with, possibly, recommendations. This latter function is especially applicable in writing progress reports on research projects. It is not so pertinent in giving an account of the progress made on, say, a construction or installation project.

In serving as a transition between the current report and the previous one, this part of the report need not be lengthy, for it is essentially a reminder to the reader—a jog to his memory. Reading

it gives him an opportunity to recall the substance of the previous reports and get into the proper frame of mind, so to speak, to read the present one intelligently. It is true that the title may partially bridge the gap between reports, for it may name the project and number the report. Something like "Boiler Installation in Plant No. 1, Progress Report No. 5" is characteristic. But even such a descriptive title is not enough, and many reports do not bear such titles (see the example at the end of this chapter). The discussion—the briefing—is needed to hook the current report securely onto the previous one.

THE BODY OF THE REPORT. With the introduction out of the way, the reporter must next tackle the body of his report—the detailed account of current progress. Probably the first point that needs to be stressed here is the importance of making this part of the report complete, accurate, and clear. This is much easier said than done, mainly because it is easy to forget the reader. It is necessary to remember that the report is not a personal record for the writer but information for some particular reader or readers about the work done. If the writer keeps this in mind, he should have very little trouble. The second thing that needs to be said concerns organization. Although some progress reports are organized chronologically with subsections covering parts of the over-all period (a monthly report might have four subdivisions, each being a running narrative account of the work done during a week's time), most of them are organized topically. For instance, a report of progress made on a dam construction job contained the following subdivisions: (1) General [interpretative comments], (2) Excavation, (3) Drilling and Grouting, (4) Mass Concrete, and (5) Oil Piping. A report of progress made on the production of an aircraft model contained these topical subdivisions: (1) Design Progress, (2) Tooling, (3) Manufacture, (4) Tests, and (5) Airplane Description. The sample progress report included in this chapter provides still another example. But these illustrations should not be regarded as prescriptions. The important thing is that the development of the main section of the report should grow logically out of the subject matter itself and the requirements of those who want the report.

Giving a careful, detailed account of work done may require the presentation of quite a mass of data. Usually such data, particularly numerical data, cannot be presented in the conventional sentence-paragraph pattern; they would be unreadable. Tables, of course, are the answer. But since you will want to make your reports as readable as possible, you will do well not to interrupt your discussion with too many tables. It is better to put them in an appendix at the end of the

report and confine yourself to evaluative or interpretative remarks about the data in the body of the report itself. Don't forget to tell the reader that the tables are in the appendix. For instance, the report on a dam construction mentioned in the above paragraph contained a table giving an estimate of quantities of material used, one on unit and concrete costs, and another giving the type and number of employees along with the amount of money paid out for each. Here is the first of them:

Estimate of Quantities—Week Ending April 25, 1943

Bid Item	*Description*	*Unit*	*Previous Total*	*This Period*	*To Date*
1	Mass concrete	cu yd	787,686	18,792	806,478
2	Steel reinforcing	lb	2,369,350	29,883	2,399,233
3	Black steel pipe	lb	213,107	666	213,773
4	Cooling pipe	lin ft	317,417	188	317,605
5	Electric conduit	lb	67,489	309	367,789
6	Copper water stop	lb	35,424	856	36,280

The presentation of data such as this in connected reading matter would be difficult, to say the least, and this is a short table—each of the others contained four or five times as much data. Although tables are a great convenience and sometimes a necessity, it is important to remember that they should not be allowed to stand alone without comment.

THE CONCLUSION. Except for one thing, the requirements of the conclusion to a progress report will depend entirely on the nature of the work reported on. If progress on a research project is being reported, for instance, it may be necessary to present a careful, detailed statement of conclusions reached—even though these conclusions have been briefly stated in broad outline in the introductory section. It may also be desirable to make recommendations about action to be taken as a result of present findings or about future work on the project. On the other hand, it is not likely that a report on the progress made on a simple machine installation, say, would require any formal conclusions or recommendations. But you are not likely to have trouble with this problem, for the nature of the subject matter will suggest naturally what should go into the

last section. There is one thing, however, which you can count on having to do in almost all progress reports, regardless of subject matter, and it is suggested by the term "prophetic" used earlier. You must tell the reader approximately what he may expect the next report to be about and what its coverage, or scope, will be. Along with this forecast it may be advisable to estimate the time necessary for completion of the entire project. Here is an important caution: Don't promise too much. It is very easy for the inexperienced worker to overestimate the amount of work that can be covered in a forthcoming period. You will naturally want the forecast to look promising, but you will not want it to look so promising that the reader will be disappointed in case the progress actually made does not measure up to your prediction.

A final word of advice: Be brief but complete and use the simplest terminology you can.

Form

We have discussed the content and presentation of the three main parts of the progress report—introduction, body, and conclusion. There remains the problem of form. Two forms are used for progress reports, the choice depending on the length and complexity of the report. They are the letter form and the conventional or formal report form. The first is used for short reports submitted to one individual, or at most to a small number. The second is used for longer reports, submitted perhaps to an individual but more often for circulation to a number of company officials and perhaps to stockholders and directors as well.

The letter report has a conventional heading, inside address, and salutation. The opening paragraph makes reference to the preceding report and identifies the nature and scope of the present one. The parts of the rest of the report are usually labeled by means of marginal headings, these corresponding to the subject matter divisions. The conventional ending is the complimentary closing, "Respectfully submitted," followed by the signature. This form is especially suitable in those organizations where the report serves primarily as a means of "accounting for" the reporter's activity. Besides, it has the advantage of the personal touch.

The letter, however, is not suitable for long reports of progress on elaborate projects submitted for wide circulation to sponsors or directors. For one thing, the letter loses its identity as a letter if it extends over a large number of pages, especially since marginal subheadings are usually employed. There may be, of course, a letter of

transmittal. But the report proper will follow the pattern described in the chapter on report format (Chapter 19).

ILLUSTRATIVE MATERIAL

The material on the following pages is a portion of a progress report. It should be examined carefully, not necessarily as a model, but as a fairly typical example of the progress reports commonly written by engineers today. Note the extent to which it conforms to the pattern just discussed. Do you think it was written for a reader thoroughly acquainted with the technical subject matter or for one without such a background?

DEPARTMENT OF ENGINEERING RESEARCH
University of Michigan
Ann Arbor

REPORT ON

The Relation of Bearing Noise to Lubrication

BY
H. B. Vincent
F. A. Firestone

Project Number 659

FOR
The Timken Roller Bearing Company
July, 1931

REPORT OF PROGRESS

ON

Project Number 659

FROM

H. B. Vincent and F. A. Firestone

TO

The Timken Roller Bearing Company

The Relation of Bearing Noise to Lubrication *

In the report for June numerous measurements on the action of various combinations of parts were given with a view to determining the best manufacturing procedure. This present report deals with the solution of the fundamental problem of why the bearing makes more noise with a heavy lubricant than it does with a light one.

It will be shown that a certain bearing having V-type rolls makes less noise with heavy lubricants than with light ones, and the F- or C-type roll has less righting moment, when lubricated with a heavy oil than with a light oil and that the roll runs partly overturned. Designs to correct this fault are discussed.

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* Reprinted by permission of The Timken Roller Bearing Company.

It is customary for title pages of reports to be headed with the name of the company or organization under whose authority they were prepared.

Notice that the opening sentence "hooks on" to the previous report by reminding the reader of its subject matter, and that this is followed immediately by a statement of purpose for the present report. Both of these necessary functions are accomplished briefly.

The second paragraph presents the conclusions reached in the present study but only in quite general terms.

Test 72.

Object: To determine the total loudness of noise produced by an A–4221–N bearing when lubricated with kerosene, with spindle oil, and with 600W oil.

Procedure: The bearing was run at 1600 r.p.m. on the master machine, and the total loudness measured in equivalent millivolts at 1000 cycles per second.

Data: The data are as follows:

Lubricant	*Millivolts*
Kerosene	17
Spindle Oil	15
600W oil	13.5

The bearing has V-type rolls.

Conclusion: This bearing acts very differently from the 465-type with self-aligning rolls. It seems probable that the difference is due to the difference in roll ends since this bearing built with ground rolls shows more quiet operation with 600W oil than with the lighter oils.

If, as suggested above, the bearings operate with the rolls partly overturned, this roll would not be so much displaced in the direction of its axis by the small angle imposed on it.

It seemed that some notion of the action of the lubricant in the bearing might be drawn from a measurement of its electrical resistance while running. A test was made to determine the resistance for the three lubricants used in the preceding tests.

Test 73.

Object: To determine the electrical resistance of a 465-type bearing when run with kerosene, spindle oil, and 600W oil in turn.

Procedure: The work support on which the bearing rests during the noise test was insulated electrically from the machine by means of a fibre washer of suitable size. The bearing was oiled and run on the master machine at 1600 r.p.m., the resistance between the cup and the machine being measured on a Wheatstone Bridge. With this arrangement the current had to pass through an oil film to enter the roll and through another to leave it. The other resistances in the circuit being small the resistance measured was that of the oil film.

The organization of the body of the report is very simple: each test made during the period is separately reported, with its own subdivisions. The subheadings will remind you of the laboratory reports you have written.

This last paragraph in this section serves as a transition to the next section.

Note that in this report no words are wasted in stating the object of the test.

Data: The data were as follows:

	Lubricant		
	Kerosene	*Spindle Oil*	*600W Oil*
Resistance in ohms	100	400	5000

As mentioned above, Standard Cup No. 1 gave a bad scraping noise when used with spindle oil. The resistance of a bearing operating under this condition was measured and gave a value of only 40 ohms.

All the above measurements were taken with a Standard cone and lapped rolls. The resistance was far from steady and the values quoted are only approximately the average.

Conclusion: The fluids used as lubricants are all good insulators so that conduction must be carried on by the contact of small spires of metal which rupture the oil film locally. If the surfaces were perfectly smooth and the lubricant able to stand the shear imposed on it, the resistance would be very great. The resistance then gives a measure of the thickness of the oil film with which the bearing operates, and the thickness is obviously greater for heavy oil.

A thicker oil film on the roll-end will decrease the righting moment on the roll. This will permit the roll to overturn more easily. Evidence that the roll tends to run at an angle is presented below.

The results of Test 72 indicate that the form of the roll end is of major importance in bearing operation. One of the simplest changes to make in this part is to give it a high polish on the running surface. This should reduce the friction and make the end very accurately symmetrical about the axis of the roll.

This operation was carried out with Roll Set 49-64 of the lapped type with polished radii and the bearing was tested with each of the three lubricants previously used. Very little improvement was noted in the noise produced, but it was noted after running that the roll ends and the cone rib showed scratches. An analysis of these scratches is of some interest.

The accompanying photographs show the scratches mentioned. While scratches in both directions are present, a careful examination of the cone rib shows that the greater number of these lines run outward in a curve which bends from a radius in a clockwise direction. The roll ends show lines bending in a contra-clockwise direction when viewed in the same way.

Computations on what should produce such lines follow.

Care is taken to specify how measurements were taken and what their accuracy is. This illustrates what was meant earlier when it was said that no important detail must be left out.

Though the conclusions reached were mentioned in a general way in the first section, they are given in detail and explained in this portion of the report—for each subdivision, in this particular case.

Note the reference to accompanying photographs and computations in the final paragraphs of this section. Comment is offered to explain the significance of the photographs: the important thing to note is that it is not left entirely to the reader to recognize meaning or meanings in the illustrations. (These photographs and computations are not included because of the limitations of space—nor is the conclusion in which a forecast is given.)

Suggestions for Writing

1. Write a progress report in letter form (see Chapter 19 on report forms) giving an account of the progress you have made to date on a long report assignment. If you are writing a research report, include in your progress report an account of library research (indexes consulted, books available on the topic, general reference works, and so on), note taking, making of illustrations, rough draft, and the like—anything pertinent, in fact. Include a statement about what remains to be done and a prediction of the anticipated date of completion. Additional reports may be made later on this same project.

2. If you are engaged in any sort of extended laboratory experiment in one of your technical courses, make a progress report on the work accomplished to date. Assume that it is being made to someone unfamiliar with the technical nature of the subject matter. Use conventional report form—title page, table of contents, and so on—but omit the letter of transmittal since the introduction can perform its function.

3. Assuming that your technical writing course is the project, write a report of the progress made during the preceding month. Do not forget to include in the beginning section a brief statement or synopsis of earlier progress which (you will assume) has already been reported. Put this in letter-report form and address it to a hypothetical educational adviser.

14

Recommendation Reports

Introduction

Because the term "recommendation report" is so frequently used in technical writing, both in textbooks and in the field, one would naturally suppose that this is a type of report with an easily identifiable kind of content and organization. In fact, however, any report that contains recommendations is a recommendation report —and almost any report may contain recommendations.

Examination of numerous recommendation reports will show that their basic characteristics differ widely. The bulk of the content of a recommendation report is probably most often interpretative, but it is not uncommon to find more description than interpretation. There is no standardized organization for recommendation reports, with the exception that the recommendations are usually stated near the beginning, or near the end, or both. The format may be almost any one of the many varieties in use. The function of a recommendation report, on the other hand, would seem at first to be fixed and stable—that is, to persuade the reader to take a certain course of action; and usually this function is indeed evident in prac-

tice. But a consulting engineer might conceivably be indifferent as to whether his recommendations were acted upon, and reflect his indifference in the tone of his report. We must conclude, in brief, that we are dealing with an ambiguous concept when we discuss recommendation reports: a considerably less exact concept than that of the progress report.

Nevertheless the vitality of the idea of a recommendation report, as shown by the wide currency of the term, is a warning that we should not treat the concept too casually. Of course what we are dealing with fundamentally is the situation (in report form) in which the abstract thinking of the laboratory and the study passes over into the realm of practical action; and the vitality of the idea of a recommendation report probably springs from a tacit recognition of the importance of this situation. Furthermore, it would be a mistake to suppose that people don't know what they mean when they use the term "recommendation report." Probably they don't always know exactly; but if your boss or your college instructor tells you to write a recommendation report about something, we strongly urge that you do not stop to itemize the ambiguities we have just been pointing out, but get busy and analyze the problem you have been given, decide upon the proper course of action, and make a forthright recommendation. That kind of procedure is what your boss or your college instructor will mean when he speaks of a recommendation report.

The only writing problems that will be new to you in a recommendation report, as the foregoing considerations suggest, are how to phrase recommendations and where to put them. Before taking up these problems, however, it will be helpful to give some special attention to reader analysis and style.

Reader Analysis and Style

Ideally, the art of persuasion would never enter into the professions of science and engineering. The scientist or engineer would investigate physical laws, or apply them to a specific problem, report his findings, and be through. The reader would need no convincing or persuading; he would be governed solely by logic. Practically, of course, things are seldom so simple.

There are two somewhat different situations to be considered: first, that in which you are given definite instructions to prepare a recommendation report, and second, that in which you volunteer a recommendation. A volunteered recommendation may be inserted into a report written primarily for a different purpose (like a progress

report) or it may be made the chief subject and purpose of a special report.

When you have been instructed to make a recommendation, you may find that it is fairly obvious what action should be recommended, and also that everybody agrees it is the proper action. This is wonderful—and not uncommon at all. But you may on other occasions find that after studying the subject (1) you don't think any action at all should be taken, whereas you either know or suspect that your superior or associates feel that some action is desirable; (2) you think action should be taken, but anticipate unwillingness to act; (3) you think a certain course of action should be taken, but anticipate that a different course of action will be favored; (4) you think action should be taken, but cannot see a clear advantage between two or more possible courses of action.

If you find that the evidence does not indicate clearly what decision should be made, the best policy is simply to say so, with an especially thorough analysis of advantages and disadvantages. This does not mean you should not make a concrete recommendation; you should—but not without making clear the uncertainties involved. This situation is found in some measure in the first report printed at the end of this chapter.

When you anticipate opposition to recommendations you have become convinced are those that should be made, you should give a good deal of thought to the tone of your report, and to methods of emphasizing the points you think do most to clarify the logic of the situation.

Don't let yourself fall into an argumentative tone. We have in our files a report from a research organization that begins with the statement, "This is a very important report." Our own immediate reaction, when first reading this statement, was a suspicion that maybe the report wasn't really very important or the writer wouldn't have thought it necessary to try so unblushingly to persuade the reader it was. It would have been a more effective report had the writer prepared a good, clear introduction, stated his major conclusions in the proper place, and added this sort of statement: "The great importance of this discovery arises from the fact that . . . ."

In general, be forthright in tone or manner, but not blunt. Instead of saying, "The present method is wasteful and inefficient," remind yourself that whoever designed the present method was probably doing the best that could be done at the time, and was not unlikely proud of his work; then you may prefer to write something like, "The proposed new method offers a considerable increase in ef-

ficiency over the present method." Or, "Certain changes in the present method will result in a substantial increase in efficiency."

Putting emphasis on the proper points demands first of all an analysis of the probable attitudes of your reader. If you do not anticipate opposition there is little problem here. If you decide that opposition is probable, a good general policy is to discuss, first, the advantages and disadvantages of the recommendation you think might be preferred to the one you intend to make—being careful to state fairly *all* its advantages; second, to present the advantages and disadvantages of the course of action you prefer; third, to give a summary and recommendation. This approach provides emphasis through relative position—the value of the preferred action being shown after the weaknesses of the alternative have been explained. Emphasis may also be achieved through paragraphing and sentence structure. For example, use of a series of short paragraphs written in short declarative sentences when you sum up the advantages of the preferred course of action will result in an especially forceful impression.

A problem as to whether or not you should volunteer a recommendation is most likely to arise when you have a positive suggestion about work in which your own official part is only routine, or about work which is not exactly part of your official duties. In the long run there is no question that the more ideas you have, the more suggestions you make, the faster you will be promoted and the more fun you will have with your work. But when it comes to volunteering recommendations in writing, two cautions ought to be observed.

First, be very sure that your recommendation is sound, and that you have shown clearly that it is sound. (In this connection, a review of the discussion of interpretation in Chapter 9 will be helpful.) Your superiors aren't going to be delighted with mere opinions.

The other caution is to be careful not to give the impression that you are trying to "muscle in" on something. This is likely to be a delicate point, and you'll be wise to think about it very deliberately. To a certain extent this difficulty can be met by avoiding the kind of phrasing used in a formal recommendation (see below) and by presenting your recommendation in the form of a conclusion. Instead of saying, "It is recommended that the temperature of the kiln be lowered 15 degrees and the drying time prolonged to 84 hours," you could say, "Better results would evidently be obtained by lowering the temperature of the kiln 15 degrees and prolonging the drying time to 84 hours."

Altogether, then, when you have recommendations to make, your first problem is to determine precisely what course of action

or what decision is best justified by the evidence; your second problem is to estimate your reader's probable attitude toward your recommendations; and your third problem is to prepare a report that will be effectively designed to make clear the logic of your recommendations to the specific reader or readers you expect to have.

How to Phrase Recommendations

To a certain extent it is possible to classify recommendations as formal and informal. An informal recommendation may consist merely of a statement like, "It is recommended that a detergent be added to the lubricant." Or, "Therefore a detergent should be added to the lubricant." In a sense, any suggestion or advice constitutes a recommendation, and the formality with which it should be presented is determined by its relation to the major problem being discussed, and by the tone of the whole report, as stated above. Usually, the more important a problem is, and the longer the discussion of it, the more need there is for a formally phrased recommendation.

A highly formal recommendation is illustrated by the following:

> After consideration of all the information available concerning the problems just described, it is recommended:
>
> That the present sewage disposal plant be expanded, rather than that a new one be constructed;
>
> That the present filter be changed to a high-rate filter;
>
> That a skilled operator be employed.

Sometimes each main clause in a recommendation written like that above is numbered. Sometimes the recommendations are presented as a numbered list of complete sentences preceded by the subhead "Recommendations" and without any other introduction. And, of course, sometimes they are simply written out in sentence form as shown in the "informal" example above, without unusual indentation and without numbers.

It is occasionally advisable to accompany each recommendation with some explanation, in contrast to limiting each recommendation to a single statement as illustrated above. An example will be found at the end of this chapter. This method is often particularly useful when recommendations are stated twice in the same report, at the beginning and again at the end; the explanations usually accompany the second statement.

Where to Put Recommendations

Recommendations almost invariably appear at the end of a recommendation report. If the report is long, and especially if an in-

troductory summary is used, they are likely to appear near the beginning as well, immediately after the statement of the problem. Particularly when they appear both at the beginning and the end, however, those at the end are likely to be stated informally, often appearing more like general conclusions than recommendations; whereas those at the beginning are more formal, usually with the heading "Recommendations."

The recommendations at the beginning are desirable, if the report is of some length, in order that a reader may at once find the major results. And it is always wise to state the recommendations at the end so that they will be the last ideas impressed on the reader's mind.

These suggestions will be made clearer by the illustrations that follow.

ILLUSTRATIVE MATERIAL

In the following pages two reports are presented to illustrate what routine industrial recommendation reports look like. The first report has recommendations only at the end; the second, near the beginning and at the end as well.

In both reports the technique of interpretation of data plays a part, but it is more prominent in the first than in the second, where the techniques of description are especially evident. Could the handling of the various special writing techniques in these reports be improved?

Report

LINDBERG ENGINEERING COMPANY

Research Laboratory *

Determination of the Deposit That Collects on the Element Coils and the Cause of Failure of the Element Coils in Type 2872-EH Furnace, Serial 2162 at Olds Motor Works, Lansing, Michigan.

Introduction

The Olds Motor Company of Lansing, Michigan have been experiencing abnormal element failures in their Type 2872-EH furnace. Mr. W. Bechtle of our Detroit Office sent in a peculiar, light brown, fluffy deposit he found on the burnt out wire coils. He found that this substance was very retentive and difficult to shake off the coil.

His report pointed out that the work being drawn in this furnace was heat treated in an Ajax salt bath and quenched into oil. He stated that although the work was washed and appeared to be clean, small quantities of salt might still be present to cause the deposit on the elements and the subsequent failure. A request was made to analyze the material to determine whether it came from the Ajax salt bath and also to determine if it were responsible for the element failure.

Procedure

Conductivity tests and a complete chemical analysis were made of the coating taken off the heating element that failed.

Discussion of the Results

The resistance of the material as received was tested with a sensitive meter, and it was found to be very high and thus not a conductor when cold. Good contact may not have been made when making the above test because of the powdery condition of the material. To verify this and also to check on the solubility, some of the substance was placed in distilled water. The resistance of the distilled water was found to be 80,000 ohms before the substance was placed in it. After the substance was placed in the water and stirred, the resistance dropped to 15,000 ohms, showing very slight solubility and conductivity. Tests at high temperatures were not made because the conditions existing in the furnace with a high voltage of about 450 to 480 could not be reproduced.

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The report on the facing and following pages is a recommendation report in which the recommendations appear only at the end, accompanied by considerable explanation. On the whole it is clear and well done, but the introduction is weak (the initial emphasis particularly), and part of what is presented under "Discussion of the Results" seems to belong more logically to the preceding section on "Procedure." The English is only fair. Apart from the English, the "Conclusions" and "Recommendations" sections are excellent.

The chemical analysis of the fluffy substance removed from the elements is as follows:

Silicon (SiO_2)	28.78%
Iron Oxide (Fe_2O_3)	46.70
Alumina (Al_2O_3)	13.06
Nickel Oxide (NiO)	1.60
Chromium Oxide (Cr_2O_3)	0.30
Barium Chloride ($BaCl_2$)	1.88
Barium Oxide (BaO)	0.57
Total	92.89%

(Balance may be Potassium and Sodium compounds that were not determined.)

The presence of barium definitely indicates that the Ajax heat treating salt is getting into the draw furnace. Barium Chloride is one of the common constituents of heat treating salts, and there are no traces of this substance in materials used in the construction of the Lindberg Furnace.

The presence of the high percentage of silica, alumina, iron oxide, and other oxides can be easily explained. The silica, alumina, nickel and chromium oxides come from the dust produced by the wear of the furnace refractory and alloy parts rubbing together under constant vibration. The iron oxide comes chiefly from the scale of the heat treated work or the scale produced in tempering the work. All of this dust is being constantly carried in the recirculating air stream over the work and through the element chamber. Under normal conditions this dust will not stick to the elements because the melting point is very high and the velocity of the air is too great to allow the dust to settle out.

With the introduction of only a slight amount of heat treating salt, however, this condition is entirely changed. The heat treating salt spalls off the work due to the difference in its thermal expansion over steel when heated in the tempering furnace and is carried with the other dust in the air stream. As work is continuously being tempered, the concentration of the heat treating salt particles becomes greater. When the heat treating salt particles are carried over the heating elements by the recirculating air stream, the salt particles strike the element and melt to its surface. (The heating element temperature may go as high as 2000°F., depending on the furnace temperature and the load.) The remaining dust from the furnace refractory and scale from the heat treated work then stick to the element.

The failure of the element then results from the material covering the insulators and making contact to the frame and the element

coil. The high voltage of 440 to 480 arcs across, burning out sections of the wire from the element. The material covering the element also acts as an insulator, causing the element to run abnormally high in temperature which also reduces its life.

Conclusions

1. The material coating the heating element in the furnace is a combination of heat treating salt from the hardening operation and refractory and oxide dust from the tempering furnace. The heat treating salt dust melts when it strikes the elements and the remainder furnace dust sticks to it.
2. The element failure is due to the conductivity of the melted heat treating salt covering the element and insulators and thus shorting to the frame. The high voltage of 440 to 480 arcs across and cuts sections out of the element coil. The substance covering the coils also acts as an insulator, causing an abnormally high element temperature which also greatly reduces its life.

Recommendations

1. The most logical thing to do is to prevent the heat treating salt from entering the draw furnace. This, however, is not quite as easy as one may first think because heat treating salts containing barium are not very soluble in hot water or caustic solutions. The solubility depends upon the amount of barium salts present in the mixture. Barium chloride itself is only slightly soluble in hot or cold water or in caustic solutions. Heat treating salts containing barium are very difficult to dissolve out of blind holes, recesses, and etc.

   The only sure way that all traces of barium heat treating salts can be cleaned from the work is by the following procedure: 1st—Clean salt and oil from quenched work in hot Oakite solution; 2nd—Rinse in hot water; 3rd—Clean in an acid solution (one part of hydrochloric to four parts of water, or a standard pickling bath can be used if care is observed); 4th—Rinse in hot water to remove acid.

   A better method would be to use a heat treating salt that is readily soluble in water. Such a salt is a compound of a mixture of sodium and potassium chlorides and is the best type of neutral hardening salt that can be used. One such commercial salt on the market is known as Lavite #130, made by the Bellis Heat Treating Company. This salt has a useful temperature range from 1330°F. minimum to 1650°F. maximum. In as much as we are not familiar with the hardening requirements, only the above general suggestion can be given in reference to cleaning all traces of salt from the work.
2. Reduce the voltage that can exist between the coils and the frame by redesigning the heating element and thus have less chance

of burning out sections of the element by arcing due to the conductivity of the heat treating salt.

We are now designing an element for this furnace in which the element hook-up will be changed to a series star circuit instead of the delta circuit now employed. Both will operate from the 460 volt line, but the voltage between the coil and the frame over any one insulator will be reduced to about 130 volts instead of the 460 volts on the present arrangement.

This will, of course, reduce the tendency for arcing when the heat treating salt and furnace dust collect on the elements and insulators. This is not, however, a substitute for cleaning the heat treating salt from the work. The subject company must do everything possible to remove the traces of heat treating salt if low maintenance is to be achieved. The redesign of the element will act as a safety factor to prevent excessive burn outs in case some heat treating salt gets into the furnace occasionally.

3. If it is found impractical to follow out recommendation 1, and the new redesigned coil we are supplying for recommendation 2 does not reduce the maintenance, then consideration should be given to rebuilding the subject furnace to gas fired instead of electric.

"Both will operate" is slightly ambiguous because of the future tense. "Both can be operated" might be better.

Report

Analysis Wing Rib Stiffener
Prepared by
Date 3-10-43

DOUGLAS AIRCRAFT COMPANY, INC.

PLANT	LOCATION	DIVISION
Santa Monica	E	Engineering

Page 1
Model C-74
Report No. 2925-18

OBJECT: To determine a more practical method of forming the C-74 wing rib stiffener.

INTRODUCTION: The need for an investigation arose from difficulty encountered in forming the C-74 wing rib stiffener (Fig. 1). When formed on the hydro-press using a conventional form block, excessive wrinkling developed. This wrinkling of the wing rib stiffener was, for practical purposes, irreparable.

SUMMARY: Three methods were investigated. The first involved the use of an ordinary form block upon which five specimens were tested. Severe wrinkling occurred on each specimen, the hand working of which would damage the metal and cause undue expense.

The second method embodied the use of a wiper plate form block. Wrinkling on the main flange was eliminated by the wiper plate, but mild wrinkling still occurred on the "c" flange. Handwork was necessary to eliminate the wrinkles.

A third method then suggested itself which would involve only one hydro-press operation. The main flange and the "c" flange of the straight section would be formed by one hit on the form block, the same hit operating the wiper plate to form the main flange of the curved section. A second operation, in which the "c" flange of the curved section is formed by handwork, completes the part.

RECOMMENDATION: It is recommended that the C-74 wing rib stiffener be formed by the third method, employing a wiper plate form block as shown in Figure 6. The process will be reduced to two operations - one hit by the hydro-press, and handworking on the "c"

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The report on the accompanying pages, entitled "Wing Rib Stiffener," illustrates the use of recommendations both near the beginning and at the end. Several photographs and sketches have been omitted, and some text which was part of a four-page appendix.

Well done for the most part, this report is confusing in one respect. Three "methods" are listed in the "Summary," and the initial recommendation refers to the "third method," but at the end of the report only two methods are listed. What has happened is that, since the third method is really a modification of the second, at the end of the report the third method is presented as subdivision "3" under "Method II," and is then commented on further in the concluding paragraph.

flange of the curved section.

NOTE: The test specimens used in this investigation differ somewhat in design from the part which will be manufactured. However, the principles involved in the tests are basically applicable to either type part, and the difference in design in no way alters the conclusions reached in the report. For further explanation, refer to Appendix A-5 and Figure 8.

PROCEDURE:

I. A series of five tests was run to determine the practicability of using a conventional form block (Fig. 2) to form the part (Method #1).

METHOD I - FORM BLOCK

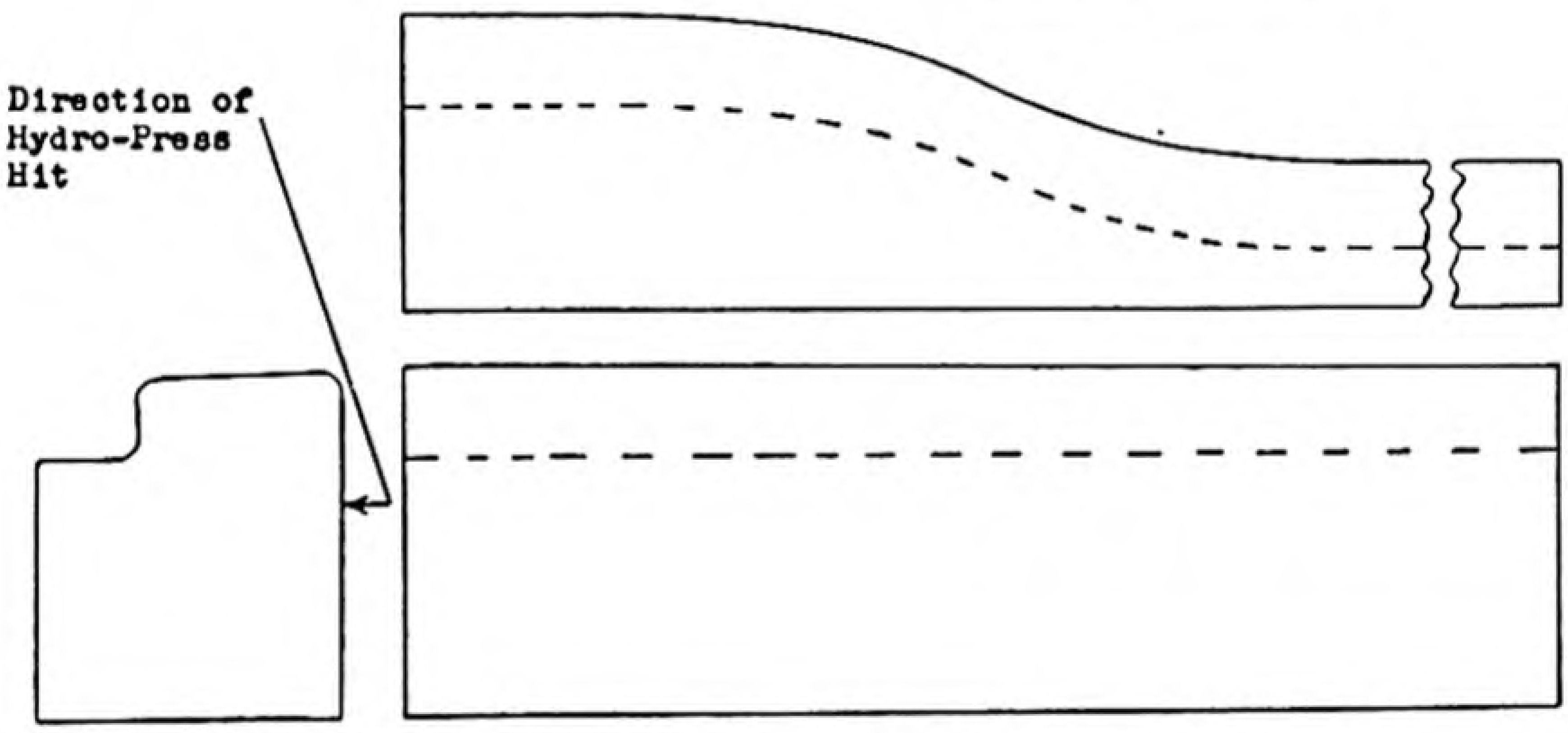

Figure 2

Figure 3 pictures the specimens used in the tests, each specimen showing the results of forming under a different set of conditions.

A. The first test was made on a 24SOAL part, the curved edge cut with hand circle cutters and not burred (left as is). The part was hit twice - once on top, to form the main flange, then turned over and hit again to set the "c" flange. No handwork was

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done on the part.

Severe wrinkling occurred near the center of the curvature on Specimen #1. This was due to the relatively large shrinkage required - 16% (Appendix A-1). The wrinkling occurred for the most part in forming the main flange. In addition, a split occurred in the concave "c" flange. The split resulted from the combination of a high elongation requirement of 21% (Appendix A-2) and from the fact that the edges were unpolished. The latter condition is conducive to splits in metal under high tension because an unburred edge is in reality a series of minute splits each constituting a weak spot. When pressure is concentrated on one of these weak spots, the weakness tends to develop into a split of major importance.

B. The next test was run on a similar part (24SOAL), but with polished edges. The part was hit on top once and not hit again to set the "c" flange. There was no handwork on the part.

No split occurred on this specimen (#2) when subject to the same conditions of elongation and shrink as Specimen #1. The splitting was prevented by polishing the edges, which removes the dangers of unburred edges. The part formed in the second test resulted from one hit of the press, whereas the two forming hits used in Test #1 produced no appreciable difference in result.

C. The third test was similar to Test #1 except that the part (24SOAL) used in the test had polished edges. The part was hit twice - once on the top, then turned over and hit again to set the "c" flange. Again no handwork was performed.

Specimen #3 differed from Specimen #1 only in the absence of a split at the lower part of the curvature. This is attributable to

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the polished edges, as previously mentioned. Wrinkling occurred with approximately the same degree of severity in all these specimens. Comparison of Specimens #2 and #3 indicates that little difference results from using two blows to form the stiffener rather than using one blow.

D. The conditions of Test #4 were identical to those of Test #3, with one additional operation. The wrinkles were handworked to obtain the best possible part.

The appearances of Specimens #3 and #4 were identical before the handworking. The handwork, consisting of hammering and trimming, produced the desired shape of the stiffener. However, certain disadvantages make this method impracticable. First, an unreasonable amount of expense and time is required to eliminate the wrinkles. Second, there is a high probability that the metal in the area of the wrinkle will be damaged by excessive movement of the metal in hammering out the wrinkle. Specimen #4 was definitely damaged by the wrinkle removal process. The damage is not discernible in the photograph as the damaged area was immediately behind the lip of the "c" flange.

E. In Test #5, 24STAL was used in place of 24SOAL. The part had polished edges and was hit on top; then it was turned over and hit again to form the "c" flange. No handwork was required in the test.

Considerable difference in performance of 24STAL and 24SOAL under identical test conditions may be noted here. Specimen #5 was subjected to the same test as was Specimen #3; yet the damage to the hardstock (Specimen #5) was much more severe. Wrinkling occurred at approximately the same place on the curvature as it did with the other four specimens, but it was much more severe in form. The greater wrinkling is due to the smaller shrinkage limits of hardstock. In addition, it will be noted that at the lower end of the curvature, a crack occurred on the bend

radius of the "c" flange. This indicates that the elongation limit for 24STAL was exceeded when the "c" flange was set. A contributory factor in the failure arose from the form block bend radius which was designed for 24SOAL and which was too severe for 24STAL. The design of this wing rib stiffener with its shrink requirements of 16% precludes the possibility of using hardstock.

II. The second method was investigated as follows:

A wiper plate form block with two stages of operation was used (Figures 4 and 4-A). The wiper plate and an extended plain form block was used for forming the main flange, the wiper plate forming the curved section of the flange. The purpose of the wiper plate is to force the metal down over the form block and "wipe" the wrinkle out of the flange. The excess metal is forced to flow toward the outer edge, thus leaving a negligible amount of wrinkling.

The second stage of the operation is the formation of the "c" flange. This stage of the operation tends to develop only mild wrinkling on the lip of the "c" flange. Test specimens are shown in Figure 5.

F. This test required the use of one 24SOAL part with polished edges, to be hit once with the wiper plate to form the top and then again on the form block to set the "c" flange. No handwork was performed.

As will be seen from the illustration, the flange of Specimen F remained unwrinkled before the "c" flange was formed. Mild wrinkling did occur when the "c" flange was formed.

G. This test was merely a second run of Test F. Less wrinkling occurred on this test; but in forming the "c" flange, there was

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insufficient metal in the lip of the flange at the center area of curvature. However, this condition was caused by inaccurate layout of the stock. It was not due to a poor forming action of the forming block.

H. In this test one 24SOAL part with polished edges was used, but it was hit only once - with the wiper plate form block. No handwork was performed.

This test was designed to show the negligible amount of wrinkling which occurs when the wiper plate is used. The great contrast between wiper plate action and rubber forming action may be noted by comparing Figures #3 and #5.

J. This test was identical to Test H, but with one additional operation. The curved section of the "c" flange was handworked.

The main flange was formed as in Test H. The curved portion of the "c" flange was formed by handwork in a relatively short period of time with no damage to the metal.

CONCLUSIONS DRAWN FROM THE INVESTIGATION:

Method 1.

1. The part can be formed with one blow of the press as easily as with two blows.
2. The edges must be polished in order to prevent splitting of the lip of the "c" flange.
3. The part cannot be formed by Method I without severe wrinkling.
4. It is impractical to eliminate the wrinkled portion by handwork because of the possibility of damaging the metal and because of the undue amount of time consumed in doing the handwork.

5. Hardstock (24STAL) is impractical for use in making the part because wrinkles which are allowed to form in 24ST cannot be removed by handwork.
6. Some other method more suitable for forming the part should be devised.

Method II.

1. A wiper plate will eliminate wrinkling on the main flange.
2. When the "c" flange is applied using a second hydro-press hit, some wrinkles still remain in the "c" flange.
3. Slightly more time is required to form the curved section "c" flange by handworking than is required to eliminate the wrinkles from the "c" flange formed by the hydro-press. However, the difference in cost is negligible.

The most feasible method of manufacture seems to be that which forms the entire part with the exception of the curved section "c" flange (Fig.6). The curved section "c" flange is added by handworking. This would produce the cheapest part as it requires only one hydro-press hit, and involves one wiper plate form block of the type shown in Figure 6. The handworking of the flange, which must be performed in either case, eliminates an extra hydro-press hit.

Suggestions for Writing

One very good subject for a recommendation report is the recommendation of a topic for a long paper, either in this course or some other. Discuss the purpose of the paper, the standards that the topic ought to meet (personal interest, availability of information, and the like) if it is to be valuable to you and suitable in general, the bibliographical guides you consulted in making up a list of source references, the probable usefulness of the specific material you found, and so on.

Other suggestions for recommendation reports may be found by consulting the list at the end of Chapter 9, on interpretation. The topics suggested there may easily be reworded so that a recommendation is called for. For instance, instead of writing on the subject, "How Satisfactory Is My Fountain Pen?" you might substitute, "Brand X Fountain Pen Is (or Is Not) Suitable for College Students."

15

Special Types of Report Organization

Introduction

Many firms have found that their written reports are most efficient and satisfactory when they are organized according to a prescribed form. The form may range from three or four general divisions to the kind of detailed sheets used in colleges for laboratory reports. The method of organizing the components of a form varies according to the materials concerned and the preferences of the firm. In this chapter we shall introduce a few of these special forms, beginning with the highly generalized type and concluding with the highly detailed. The problem of format is discussed in Chapter 19 and will not be taken up here.

Generalized Forms

The principle underlying the policy of prescribing certain major divisions for the organization of a report is usually to make the report convenient to use. Convenience is often achieved by organizing a

report in a different way from what would naturally be suggested by the subject matter involved. In a report on a series of tests, for example, it would seem natural to present the results of the tests toward the end of the discussion, whereas convenience is often served by presenting them near the beginning: some readers will want to know only the significant results without having to examine the rest of the report. Furthermore, a report may go to several readers, some of whom are not technically trained. This situation may be met by providing a preliminary nontechnical statement followed by what amounts to a restatement of the same material but in more detail and with the addition of technical material.

The General Motors Institute, for example, recommends the following organization:

1. The statement of the purpose of the report
2. A summary of the findings, conclusions, or recommendations
3. Supporting expansion of the steps which lead to the findings, etc.
4. Evidence in support of findings, etc.

In this organization, parts 1 and 2 are stated in a form intelligible to the nontechnical reader, part 3 is a technical discussion of method and interpretation of results, and part 4 is a presentation of data in support of 2 and 3.

A similar purpose may be seen in the form used at Battelle Memorial Institute:

1. Covering letter (one page, nontechnical)
2. Introduction (half-page to one page, nontechnical summary)
3. Technical summary
4. Body
5. Section on "Future Work"
6. Appendices

Part 5 of this form is intended to apply primarily to progress reports, a type of report that is especially important in a research organization like Battelle.

The National Advisory Committee for Aeronautics prefers a more conventional organization:

1. Summary
2. Introduction
3. Symbols [They say that all symbols should be defined.]
4. Description of apparatus
5. Test procedure
6. Precision [Statement of probable accuracy of measurements, where pertinent.]
7. Analysis and discussion

8. Conclusions
9. Appendix
10. References
11. Illustrative material

In a form used by a large construction company that prefers to remain anonymous, what amounts to an introductory summary is found, the summary proper following the statement of purpose and scope. The major components of the form are these:

1. Purpose and scope
2. Summary
3. Conclusions, recommendations
4. Text
5. Appendix

There are two general comments that should be made about the forms that have been shown.

In the first place, almost all firms state that such forms should not be regarded as absolutely binding, but should be modified by the writer if circumstances require—the implication being, however, that circumstances won't usually require much modification. The flexibility of the forms may be seen in the use of the appendix, a division that appears almost universally. The appendix is primarily intended to contain data that support the discussion and the conclusions in the body of the report. Obviously, the decision as to how much of the data should go into the appendix and how much should be introduced directly into the discussion must be governed by the particular problems involved in each individual report. In effect, the requirement of an appendix is thus merely a recognition of the principle that the discussion should not be cluttered up with unnecessary details, but that the details should be available to prove the soundness of the discussion. The forms may be regarded as inflexible, on the other hand, in view of the fact that major divisions are prescribed and that a young engineer will naturally be reluctant to make any modification of these major divisions.

In the second place, what about the relation of these standardized forms to the whole problem of types of reports? If all the reports issued by a given firm can go into one or two standardized forms, does it follow that one form is actually suitable for several types of reports? Frankly, we are raising this question simply because we thought you might be puzzled about it if we didn't, and not because we believe that it matters. For several reports issued in one form by firm A, it is not unlikely that firm B would require two or three different forms. And that is about all we need say here—except to sug-

gest that you notice how easily the Battelle form, in particular, would accommodate both of the types of reports discussed in preceding chapters: progress and recommendation reports.

There is one other commonly used form to be mentioned before we turn to the highly detailed variety. That is the memorandum report. The form used looks like this:

(*Date*)

To ______________
From ______________

The recipient's name is written after "To" and the sender's name after "From." Usually the sender puts his handwritten initials at the bottom of the sheet. Sometimes other items are printed on the page, like Subject ______________, File ______________, Project No. ______________, or any other information that will prove useful. The memorandum report is essentially a rather informal communication between acquaintances, usually employees of the same firm, about a project with which each is familiar. As with all reports, the content and style are determined by the relationship of sender and recipient.

Detailed Forms

A detailed, printed form is often a great convenience in making routine reports. Thousands of such forms are in daily use. The one shown on the facing page is a fair representative of the type.

It might seem that in a form report, for once, there is no problem of reader analysis; but not so. It is wise to give a little thought to such matters as symbols, abbreviations, systems of units in stating values, probable accuracy of measurements, sampling techniques. Don't use a symbol that your reader won't recognize. Remember that an abbreviation that looks clear as crystal to you may be puzzling to somebody who is not intimately acquainted with what you have been doing. Or, if you have taken measurements in the British gravitational system only to discover that everybody else in your organization is using the metric absolute, you'd better convert your values. In brief, give some attention to the needs and knowledge of your reader.

The same attitude of consideration for the reader should lead you to think carefully about what help you can give him in the "Remarks" or "Comments" section, if such a section is provided. If certain measurements, for instance, were taken under conditions of unusual

LINDBERG ENGINEERING COMPANY

SERVICE REPORT

DISTRICT OFFICE ___

FAH-PEB-ENG. FILE
CHS-LAS-NKK
AWL-SER. FILE
LCK-GLL
LHR
RKR

CUSTOMER ___ DATE ___
STREET ___ S. O. APPLICABLE ___
CITY ___ FURNACE TYPE ___
PERSON CONTACTED ___ SERIAL NO. ___
SERVICE TIME: Labor ___ hrs. Overtime Hrs. x 1½ ___
Travelling expenses $ ___

1. List other jobs worked on, for division of traveling expenses: ___
2. Reason for call: Customer request ___, New installation ___, Unscheduled stop ___, Repair order ___, Other ___
3. KW rating ___, Tested line amps ___, Volts ___
4. Fan speed ___, Motor HP ___, Motor amps ___, Volts ___, Phase ___, Cycles ___
5. Date we last serviced equipment: first call ___, 30 days ago ___, 60 days ___, 90 days ___, Other ___
6. Was customer satisfied with equipment before trouble? Yes ___ No ___ If not, why not? ___
7. Does customer have instruction booklets, wiring diagrams, parts lists? Yes ___ No ___ If not, which should be sent and to whom? ___
8. Furnace use: hardening, annealing, tempering, or other ___
9. Material being heat treated and description ___
10. Approx. weight each charge ___ lbs. gross, ___ lbs. net. ___ Aver. lbs. per hr. net.
11. Time: Total cycle ___, Control temperature ___
12. REPORT AND RECOMMENDATIONS: ___

SIGNATURE OF SERVICEMAN ___ Have you listed extra material used? ___
Comments by service supervisor or District Manager ___

(a) Chargeable ___ (b) Not chargeable ___ Why? ___

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difficulty, a short explanation might relieve your reader of undue concern over slightly erratic results.

Finally, it is worth noting that the impersonality of the printed form is sometimes a temptation to be careless about the neatness of a form report. Needless to say, a neat report can be expected to make a better impression than a sloppy one.

Conclusion

The few special forms of organization which have been shown in this chapter provide only a glimpse of the multitude of varieties in existence. It quickly becomes apparent, however, that there is nothing really new in these forms for the person who has a knowledge of the fundamental skills of technical writing.

The content of this chapter will be given added meaning if you will turn to Appendix C, where you will find reproduced the instructions issued to employees by the Research Division of The Texas Company concerning the writing of what they term the Partial Report.

16

Oral Reports

Introduction

The purpose of this chapter is to make a few practical suggestions about talking with people. For the most part it will be concerned with talking rather formally to an audience but some attention will be given also to conferences. This chapter is not a substitute for a course in speech, nor for reading a good textbook on speech*—both of which we strongly recommend. This chapter should instead be regarded as a brief introduction to a broad and important subject. Emphasis will be given to speech problems especially common in the technical field.

Most of what has been said earlier in this book about the organization and language of technical writing applies to speaking on technical subjects as well. The discussion that follows will be confined to factors that appear only because the form of communication is oral rather than written.

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* See C. K. Mawhinney and H. A. Smith, *Business and Professional Speech* (New York, 1950), and H. M. Karr, *Your Speaking Voice* (Glendale, Calif., 1946).

Making a Speech

To be an effective speaker you must know how to use your voice properly, and how to maintain a good relationship with your audience. These will be our first subjects. But let us hasten to add that these subjects aren't as formidable as they sound. Actually, as you will find, the chief need of the novice speaker is simply the application of common sense to his problems—and practice. In addition to the subjects mentioned we will comment on transitional material, graphic aids, and the question period at the end of a talk.

THE VOICE. It is impossible to become a polished speaker without making speeches. Practice is unquestionably the most important single element in acquiring skill. The fact is, advice on how to speak is often ineffective until practice begins to lend meaning to it.

Fortunately, there is one aspect of speechmaking that each of us practices every day, at least to some degree. We all talk. We all say words. So we might as well practice saying words in a way that is pleasant to hear and easy to understand. Here are four suggestions that are helpful, whether you are talking to one person or one hundred.

1. Relax. Tenseness causes the muscles in the throat to constrict and raises the pitch of the voice. Your lungs are a pair of bellows forcing air though the vocal cords. The force is applied by muscles in the abdomen. When you are relaxed and speaking naturally you can feel the vocal cords vibrating easily.

2. Open your mouth. Speaking with your mouth insufficiently opened is like putting a mute on a trumpet. This fault is one of the commonest sources of indistinct speech. If you find you're having trouble in this respect you'll probably feel that you look ridiculous when you first start opening your mouth wider. Look in a mirror. Watch other people.

3. Use your tongue and lips. We remember a student who announced he was going to explain how to graft ceilings. It sounded ominously political, until it turned out he meant "seedlings." You can't say a "d" or a "t" without using the tip of your tongue. Nor can you say "b" or "p" without using your lips. Repeat the alphabet and notice the muscular movements required for the different sounds. It's a mechanical problem. As with opening the mouth, you may feel foolish if you start using your tongue and lips more than you have been accustomed to. Of course you may sound foolish, too, if you overdo it. Make the sounds clearly, but not affectedly. Listen to a good radio announcer.

4. Avoid a monotone. It's hard for a speaker to interest an audience, or a companion, in a subject in which he doesn't sound interested himself, and there is nothing interesting in a monotonous drone. Enthusiasm is naturally shown by a variation of the pitch of the voice to match the thought being expressed. How many shades of meaning can you give the following sentence by varying the pitch of your voice? "You think he did that?"

Some other suggestions that are also related to the problem of using your voice to best advantage are these:

1. Pronounce syllables clearly. Don't substitute "Frinstance" for "for instance." Be sparing of the "I'm gonna because I gotta" style of pronunciation.

2. Give a little attention to the speed with which you talk. Moderation is a good principle: neither very fast nor very slow.

3. Try to talk along smoothly, with fairly simple sentence structure, and without repeated "and-uh's," or habitual pauses between groups of words. It is probably best not to think much about sentence structure in your first few speeches. Concentrate on what you have to say and keep going. But you can practice good sentence structure every day in conversation.

4. Speak loudly enough so that everyone you are addressing can hear easily; but don't blast people out of their seats.

Your Relationship with Your Audience. The audiences you can expect to address as part of your professional work will be made up of people who are seeking technical and economic information, not a show. Typically, you may expect to address fellow members of professional societies, fellow employees conferring on special problems or meeting on special occasions, and so forth. Aside from reports made in college classes and seminars, the young engineer is likely to do his first speaking before a chapter of a professional society.

With such audiences your relationship should be unaffected and unassuming, but at the same time confident and businesslike. You should by all means avoid anything approaching what is sometimes called florid oratory. Say what you have to say as directly and simply as possible.

In regard to posture, the best advice is to be natural—unless nature inclines you toward sprawling limply over the table or lectern. Stand up straight, but not stiff, and look at the audience. If you feel like moving around a bit, do so: but don't pace, or walk away from a microphone if a public address system is being used. If you feel like emphasizing a point with a gesture go right ahead—but don't make startling or peculiar flourishes that will interest the audience more

than what you are saying. In general, it is wise to move slowly. Don't do anything (like toying with a key chain) that will draw attention away from what you are saying.

Above all, try to act like a human being, not a speechmaking automaton. Try to convey to the members of your audience a feeling of interest in your subject; show that you enjoy talking with them about it. A particularly useful device is to bring in occasional references to personal incidents involving yourself or your co-workers, incidents that have some relation to your subject and may be used to illustrate a point. People are always interested in other people, and an appropriate personal anecdote may warm up and give life to an otherwise dull body of information.

What can be said about preparing for such a performance? You can choose among three basic possibilities. You may read your speech from a manuscript, you may memorize the speech from a manuscript, or you may deliver it "off the cuff," using a few notes if necessary.

The last method, with or without notes, is usually very much to be preferred. It creates an impression of spontaneity and naturalness that is greatly to be desired. The use of notes is not a significant barrier to this impression, and is a considerable support to self-confidence. Very often, however, custom calls for, or sanctions, the reading of a paper. This method is especially desirable when the material to be presented is complex, as it is likely to be in meetings of professional societies. The possibility that you would need to commit a speech to memory word for word is very remote.

If the speech is given extemporaneously and notes are used, it is generally wise to put them on small cards, to type them or write them clearly, and to indicate only major headings. Too much detail in the notes might result in confusion. You might lose your place.

The initial preparation of the speech, whether notes are used or not, is like the preparation of any report. That is, first, an outline should be made (some differences in content will be noted later). If the speech is to be memorized, or read, the outline is used as a guide in writing the manuscript. If the speech is to be delivered more spontaneously, the writing step is omitted and the outline becomes a guide for practice (to a friend or relative) and a basis for the notes.

Naturally, you will want to learn all you can about your subject. Make it a point to know more about every phase of it than you expect to reveal. This extra information is like armor between you and the fear of running out of something to say when you get up to speak.

It may be helpful to read something aloud, in private, at your normal speaking rate in order to count the words a minute and thus

estimate the number of words you'll deliver in the time allotted to your speech. But remember that almost everybody uses more words to cover a given subject when speaking than when writing. Don't underestimate the length of your talk and keep your audience longer than they expected: they won't like it.

Finally, there is the problem of nervousness. You may feel about your first few speeches that, as crusty Dr. Johnson said of women taking up preaching, it's not a question of doing it well but of doing it at all. Nervousness is best regarded simply as a nuisance that will diminish with experience. Most people never do get over feeling a little trembly when they first arise to speak. There are two sources of comfort in regard to this matter. One is that you are almost certain to find that after you have been on your feet a few minutes the going is easier. Speak slowly at first, and pause for a good breath now and then. The other comfort is that your nervousness will be less apparent to the audience than you think. We sat in the front row of an audience to which a young engineer was making one of his first speeches, one evening, and were thinking what a fine job he was doing, and what composure he had, when we just happened to notice that the knees of his trousers were vibrating at what we roughly estimated to be ten cycles a second. He made an excellent impression, and it is doubtful that anybody else in the room knew that his knees were shaky. Speak whenever you have the chance; experience will put you at ease.

Maintaining an effective personal relationship with an audience is an exceedingly important part of a speech, but so is maintaining clarity. In this connection transitional devices deserve a comment.

INTRODUCTIONS, TRANSITIONS, AND CONCLUSIONS. Two problems faced by a speaker which are not faced by a writer are that an audience cannot be expected to give unwavering attention to what the speaker says, and that the audience cannot turn back to review an earlier part of a speech. Consequently, the speaker is under a heavy obligation to provide clear introductions, transitions, and conclusions. There is nothing new in principle here, and you need anticipate no special difficulty provided you give careful thought to the matter. Sometimes, if you are using notes, it is helpful to indicate points at which transitions are needed. A glance at the headings on the card will supply their content.

A third problem that should be mentioned is the possible need for a more dramatic introduction in a speech than would seem necessary in a written report. We said earlier that, for the kind of audience you are likely to have, you should be supplying information rather

than putting on a show. That statement holds true; nevertheless, it is almost inevitable that a speaker will find it desirable to use certain devices to heighten interest (still far short of putting on a show) that would seem out of place in a written technical report. One such device that has already been mentioned is simply an attempt to make the whole delivery animated and enthusiastic; a second is the use of personal anecdotes; a third (this one will be discussed in a moment) is the use of graphic aids with the purpose of lending drama and emphasis to your discussion; a fourth is the use of a dramatic introduction or conclusion.

Such an introduction is more easily illustrated than discussed abstractly, and we suggest you turn to Mr. Galt's speech, *Cold Facts*, beginning on page 386, and compare the introduction to this speech with the introduction to his article on the same subject. It is worth noting here, however, that caution is always necessary in an attempt to be dramatic. If you feel uncertain as to whether the attempt may succeed, better not try. Observe Mr. Galt's elimination of the joke about the peanuts that appeared in an early version of his talk.

GRAPHIC AIDS. Four principles to remember about the use of graphic aids are these:

1. Use graphic aids if you can—so long as there is no special circumstance that would make them inappropriate. There are almost unlimited possibilities as to types: graphs, tables, flowsheets, objects that can be held up by hand or specially mounted, slides, moving pictures, sketches on a blackboard. If you draw sketches on the blackboard do it beforehand if possible. Try not to have to let the audience sit in silence while you draw, but don't talk to the blackboard as you draw.

2. Don't use too many graphic aids. If you keep popping up with new gadgets the total effect may be spoiled.

3. Make sure that all your graphic aids are properly located and are of sufficient size so that everyone in the audience can see them easily.

4. Keep your graphic aids simpler than would seem necessary in a written report on the same subject. And don't use any aid (like certain types of graphs) that some members of your audience won't understand.

ANSWERING QUESTIONS. You may be requested to answer questions after the speech proper is terminated. Naturally, the best preparation for this part of your performance would be to acquire such a thorough knowledge of your subject that you could answer any

question promptly and precisely. Needless to say, such omniscience lies beyond the reach of most of us. What, then, is to be done?

In the first place, prepare yourself as thoroughly as you can, and then try not to worry about the question period. Chances are it won't be half the ordeal you might imagine. If you don't know the answer to a question, say so. A simple statement to the effect that you are sorry but you just don't know the answer is preferable to an attempt to bluff or to give an evasive answer.

In the second place, be considerate of the questioner. He may be a little nervous himself, and put his question more sharply than he really intended; or he may ask a foolish question. Remember, in these respective cases, that a soft answer turneth away wrath, and that the quality of mercy is not strained.

In the third place, don't try to answer a question you don't understand. Ask politely for a restatement.

In the fourth place—and also in connection with the preceding comment—make sure that the audience has heard and understood the question before you answer it. If a chairman is running the meeting he may take care of this problem, repeating questions when necessary in order to clarify them or make sure that everyone has understood. If he does not, or if there is no chairman, then you should assume the obligation yourself. You can start your reply with some such statement as "If I understand correctly, you are asking whether . . . ."

Finally, it may be necessary for you to bring the period to a close. If a specific length of time has been allotted for questions, the time limit should be respected. You should, however, try to gauge the feeling of the audience. If there is reason to think that most of the audience would like to continue, you can suggest that the time is up but that anyone who cares to may stay and go on with the discussion. In any case the audience as a whole should not be kept against its will merely because two or three persons persist in raising questions. You can usually achieve a graceful halt by declaring that time will permit only one more question.

Conferences

A large portion of almost every professional man's time is taken up by conferences. These conferences may involve only two people, or many people; and they may vary from nothing more than informal conversations to highly formalized group proceedings. Your preparation for and conduct in a conference deserve serious thought.

1. Try to formulate ahead of time the purpose of a conference. Is

the purpose to clarify a problem? To single out feasible alternatives? To make a final decision on a course of action? It is easy to permit the words "Let's get together and talk things over" to lull one into a passive state of mind in which problems that should have been thought out carefully beforehand are not even recognized until the conference is in progress, with a resulting waste of time and energy.

2. Try to formulate your own objectives before you go to a conference. Your chances of making a significant contribution are very much greater if you know your own mind before discussion begins than if you drift into the meeting like a boat without a keel. On the other hand, you should go equipped with a rudder as well as a keel so that you can change direction if the conversation opens up facts and points of view that had previously escaped you. Don't be stubborn.

3. Make a guess as to the respective attitudes of the people in the meeting. This is not a new problem: it is simply the principle of "reader analysis" carried into the conference room.

4. Take some time to speculate on how things are likely to go. Try to think of the conference as a structure. A skilled chairman can lead a group of people through a series of deliberations with an ease and clarity little short of astonishing when viewed in retrospect. He can do this—for one reason—because he is thinking of the situation as a whole and not letting progress bog down in irrelevancies. He knows where he's going. Other members of the group cannot direct the discussion quite so freely as the chairman, but can nevertheless accomplish much by well-timed suggestions.

5. A last bit of advice is that you give some attention to your oral delivery as you engage in discussion, according to the principles suggested earlier. In some respects, more skill and flexibility are required in the conference room than on the lecture platform. The situation is less under the speaker's control, and he must adjust himself quickly as it changes. Voice control is particularly important. We are all familiar with complaints about people whose voices are so loud in conversation they can be heard in the next block. It is probably true that certain types of people are actually offended by being addressed in an especially loud voice; but some psychologists assert that there is also a type of personality that is offended by an especially soft voice. People with this type of personality, it is said, tend to feel that anyone who addresses them in a soft voice must dislike them or he would "speak up."

At any rate, remember that your voice is an important part of your personality, and in the close quarters of a conference it should be used with care. If you avoid either roaring or whispering, enunciate

clearly but not affectedly, and pronounce your words without slurring syllables, you need have no worry.

Summary

The best advice we can give you is to take a course in speech, and to speak whenever you can. Meanwhile you can help yourself by making sure that you are enunciating distinctly, with adequate movement of mouth, lips, and tongue; that you are varying the pitch of your voice effectively; and that you are pronouncing words without an irritating or confusing slurring of syllables.

You can watch the technique of speakers you hear. Do they use their voices well? Do they interest you in their subjects, and seem interested themselves? Is their posture suitable? Are their speeches well organized? Are introductions, transitions, and conclusions clear, so that it isn't easy to get lost? Have they employed graphic aids to best advantage? Can they handle a series of questions smoothly? And of course whenever you get a chance to speak, you can practice these techniques yourself.

In conferences and discussions that you participate in you can practice formulating purposes and deciding upon your own objectives. Also, you can try to guess the attitudes of the other participants and to predict the probable course of the discussion. Make mental notes on the chairman's handling of the general course of the discussion. Finally, use your voice effectively.

Suggestions for Speaking

1. Bring to class an article from a magazine or professional journal and give a brief analysis of its construction. Discuss the introduction, particularly subject, purpose, scope, and plan. Write the main headings in the organization of the article on the blackboard, and comment on the logic of the organization. Discuss the use of transitions. Discuss the conclusion or summary. Don't choose a complex article, nor one more than 3000 words long. Time: three to five minutes.

2. Give a short talk based essentially on one of the special techniques discussed in Section Two. For instance, describe a simple device like a miniature flashlight. Time: three to five minutes.

3. Take one aspect of your library research report as your topic, and discuss it in detail. Time: ten to fifteen minutes.

17

Business Letters

You will probably have to do a lot of letter writing. Most professional men do. And the more successful you are the more correspondence you are likely to have to carry on. This chapter may be taken as a guide to the form and layout of letters, to the handling of style and tone, and to the organizing of a few selected types of letters. These topics will be discussed in turn, after a preliminary review of the elements or basic parts of a letter.

There are a great many details and refinements in the art of letter writing that lie beyond the scope of this chapter. In the future, as correspondence assumes an increasingly important place in your work, you will find it useful to consult such books on letter writing as are listed in Appendix A. For the present, this chapter should be adequate.

The Elements of a Business Letter

The elements, or parts, which normally appear in a letter are the heading, the inside address, the salutation, the body, the closure, and the signature. Additional elements which appear in some letters are the subject line, the attention line, and notations about enclosures,

distribution, and the identity of the stenographer. We shall discuss each of these elements before commenting on their over-all layout and appearance on the page.

THE HEADING. The heading of a letter includes the sender's address and the date. Business firms ordinarily use stationery with a printed heading containing the name of the company and its address, and frequently other information—the names of officials, the telephone number, the cable address, the company motto. When letterhead stationery is used, therefore, the writer need add to the heading only the date, either directly beneath the printed heading or to the right of center so that it ends, roughly, at the right margin.

If you write a business letter on stationery without a letterhead, you will need to put down, at the right and in order, your street address, the name of the city and state in which you live, and the date of the letter, as in the following example:

4516 Ramsey Avenue
Austin 5, Texas
October 15, 19—

Note that the postal zone number appears after the name of the city.

THE INSIDE ADDRESS. The inside address includes the full name and business address of the person written to, just as it appears on the envelope. Particular care should be exercised to spell the addressee's name correctly, and courtesy demands that his name be prefaced with "Mr." or an appropriate title. Business titles, by the way, should not precede a name; they may appear after it, separated from the surname by a comma, or on the line below. Compare the following illustrations:

Mr. John C. Doe, President
American Manufacturing Company
110 First Street
Houston 22, Texas

Dr. John C. Doe
Director of Research
Wakey Products, Inc.
1410A Grand Avenue
Detroit 2, Michigan

In writing the name of the company or organization, take pains to record it just as the company does. For instance, if the company spells out the word "company" in its correspondence, you should spell it out too, rather than abbreviate it. This is simple courtesy.

If you must write a letter to a company but do not know the name of an individual to whom to address it, you may address simply the company or a certain office or department of the company. Deletion of the complete first line in either of the examples above would leave a sufficient address. When a letter is officially addressed to a com-

HEADING → 1201 Linwood Avenue
Peoria, Illinois
February 16, 19--

Wakey Products, Inc.
1410A Grand Avenue ← INSIDE ADDRESS
Detroit 2, Michigan

Gentlemen: ← SALUTATION

I would appreciate it if you would send me your catalogue of home movie equipment, as advertised in your Circular 33-C.

If you handle stereoscopic cameras and equipment, I would also be grateful for information about what you have. I am especially interested in securing a projector.

BODY OF THE LETTER ↑

Yours truly,
↖ COMPLIMENTARY CLOSE

Richard Roe

Richard Roe
↖ TYPED SIGNATURE

Fig. 1. Elements of a Business Letter

pany but the writer wishes some particular individual or office of the company to be sure to see the letter, he may use an "attention line." Placed a double space below the inside address, or below and to the right of the inside address, this line has the word "Attention," or the abbreviation "Att.," followed by a colon and the name of the proper person or department, as shown here:

Wakey Products, Inc.
1410A Grand Avenue
Detroit 2, Michigan

Attention: Head, Drafting Department

Gentlemen:

At least a double space should be left between the heading and the inside address. Further comment on this point will be found below in the section "Form and Appearance."

THE SALUTATION. The salutation or greeting is located a double space below the last line of the inside address and flush with the left-hand margin. In formal business correspondence, "Dear Sir" is always acceptable in greeting an individual man. The greeting "Sir" should be reserved for very formal letters, and the even more formal "My dear Sir" can probably be dispensed with altogether; to most persons, it has a stilted, artificial sound. More informal than "Dear Sir" and more suitable when you are acquainted with the individual you address is "Dear Mr.——————." The latter greeting is used more than all others, with the possible exception of "Dear Sir." In addressing a company, or a group of men, use "Gentlemen." When writing to a woman or a group of women, use the equivalent of the forms just noted (Dear Miss——————, Dear Mrs.——————, Dear Madam, Mesdames).

Remember that the only acceptable mark of punctuation following the greeting is a colon. The comma is satisfactory in personal letters, but not for business letters. Too often we see an even less satisfactory mark—the semicolon. It is always incorrect.

THE BODY OF THE LETTER. The body of the letter is, of course, its message, or what you have to say to the addressee. In a general way, we can say that the body of most letters is made up of three parts: (1) the introductory statement identifying the nature of the business the letter is about or the occasion for it, along with references to previous correspondence if appropriate or necessary; (2) the message proper; and (3) the closing paragraph, often a purely conventional statement. Later on in this chapter we shall have something more to say about the style and organization of certain types of letters. The body of the letter begins a double space below the salutation.

THE COMPLIMENTARY CLOSE. The complimentary close is the formal way of signalizing the end of the letter. It is ordinarily a conventional expression which should correspond in formality with the greeting. Standard closings are as follows:

Yours respectfully, or Respectfully yours
Yours truly (not Truly yours), Yours very truly,
or Very truly yours
Yours sincerely, or Sincerely yours
Yours very sincerely, or Very sincerely yours
Cordially yours

The first of the closings listed, or a variant, "Respectfully submitted," is proper for letters of transmittal to superiors, letters of application, or for any letter in which you wish to show special respect to the addressee. "Cordially yours" is suitable only when you are personally acquainted, on a basis of equality, with the person to whom you are writing.

Conservative practice calls for a comma after the closing, although some letter writers nowadays omit it. Only the first word of the closing should be capitalized. Although many letter writers like to place the closing so that it ends in alignment with the right-hand margin, accepted practice approves of its being placed anywhere between the middle of the page and the margin, a double space below the last line of the text.

THE SIGNATURE. Directly below the complimentary close and aligned with it appears the typed signature of the writer of the letter. The typed signature should be placed far enough below the closing so as to allow plenty of space for the handwritten signature. Four to six spaces are about right.

Often the writer will need to include his business title ("Chief Engineer," for instance) and sometimes the name of the company or department of a company for which he is writing the letter. The business title is placed either before or below the typed signature. The use and location of the name of the company or department depend upon circumstances. The name of the company or department should appear below the signature only if it does not appear in a printed heading. But there is one exception. If you use a business title, like "Manager," which indicates your relationship to a department or section but not to the entire company, then the department or section should be stated after or below the business title even if the department is also identified in the heading. You will almost certainly have company letterhead stationery for official correspondence, but you may not have a departmental letterhead. The name of the company may appear *above* the signature, however, if you wish to emphasize the fact that you are speaking only as an instrument of the company and not with personal responsibility. The following examples illustrate various forms.

Cordially yours,
John C. Doe
John C. Doe

Yours very truly,
John C. Doe
John C. Doe, President

Yours sincerely,
John C. Doe
John C. Doe
Chief Technical Advisor

Yours very truly
John C. Doe
John C. Doe
Chief Technical Advisor
Research Division

Very truly yours
AMERICAN MANUFACTURING CO.
John C. Doe
John C. Doe, President

MISCELLANEOUS ELEMENTS. Several other items may be necessary or useful parts of a business letter. They include a notation identifying the stenographer, an indication of enclosures, a distribution list for copies of the letter, and a subject line. The stenographer identification consists of the sender's and the stenographer's initials, separated by a colon or a slant line. This notation is placed at the left margin, either directly opposite the typed signature or two spaces below. If there are enclosures to the letter, the abbreviation "Enc." or "Encl." is typed just below the identification notation. Many writers indicate the number of enclosures in parentheses after the abbreviation, as "Encl. (4)." If copies of the letter are distributed, the phrase "Copies to" or the abbreviation "cc" is typed at the left margin, below the identification notation, and below the enclosure notation, if there is one, and the names of those receiving a copy are listed below it. If a subject line is used, it appears either just below or below and to the right of the inside address. Most of the items discussed above are illustrated in Figure 2.

Form and Appearance

Although the content of a letter is of first importance, attractive form is also necessary if the letter is to be effective. Good appearance requires that the materials used for the letter be of good

quality, that margins and over-all layout of the letter on the page be pleasing to the eye, and that the spacing and arrangement of the elements be in accord with accepted conventions of good taste. And the letter must be neat.

The paper chosen for business correspondence should be a high quality white bond, 8½ by 11 inches in size, and of about 24-pound weight. If the letter is typed, as business letters are, the typewriter ribbon should be new enough so that it will make firm, easily legible letters; if it is handwritten, black, blue, or blue-black ink should be used. Other colors of ink are not generally considered to be in good taste. Carbon copies should be made with new carbon paper on good quality "onionskin" paper.

Attractive appearance calls for a minimum margin of at least one inch on all sides. Margins will have to be increased all around, of course, for letters which do not occupy a full page. In determining the width of margins for letters not requiring all the available space of the page, you should set them so that, within reasonable limits, the letter-block has about the same proportions as the sheet of paper. By "letter-block" we mean that area which would be encompassed by a rectangular figure drawn to enclose all the elements of the letter. Keeping these proportions means that, except for very short letters, the letter-block will have greater vertical than horizontal extension. In other words, when short letters are written, the side margins as well as the top and bottom margins must be increased. Although an experienced stenographer can estimate accurately from shorthand notes about how wide the margins should be set, the inexperienced letter writer will probably have to type a trial effort or two before attractive placement can be achieved. The letterhead, by the way, is ignored in determining over-all layout of the letter on the page. It is permissible to allow a somewhat narrower margin at the top of the page than at the bottom, about a 2:3 ratio being acceptable. This means that the center point of the letter may be slightly above the actual center of the page.

Balanced margins on the left and right sides of the page are desirable, but it is impossible to keep the right margin exactly even all the way down the page because of the necessity for dividing words at the end of a line, or the necessity for not dividing words. Words must be divided between syllables or not at all. In general it is best to avoid divided words as much as possible. A dictionary may be consulted to find the correct syllabication of words if you are uncertain of syllable division.

In letters that are more than one page long you should write the

WAKEY PRODUCTS, INC.

Education Department

General Office Newark, New Jersey

1410A Grand Avenue
Detroit 2, Michigan
October 17, 19--

American Manufacturing Co.
110 First Street
Houston 22, Texas

Subject: Training Films

Attention: Mr. Richard Roe

Gentlemen:

In reply to your letter of October 12, I am glad to say that we have several training films now available that would be suitable for the needs you described. I am enclosing two pamphlets which will give you an idea of the contents of these films. Also, I am requesting a representative from our Dallas office to call upon you within the next week.

Very truly yours,

Joe C. Doe

Joe C. Doe, Manager
Education Department

JCD:wh
Encl. (2)
cc: Mr. Joseph Smith

Fig. 2. A Typical Business Letter

name of the addressee, the page number, and the date, on page two and any additional pages. This "endorsement," one acceptable form of which is illustrated on page 284, appears just below the top of the page. The text begins two or three spaces below the endorsement, if it occupies the full page, and about eight spaces below if it occupies only a portion of the page.

Mr. John C. Doe — 2 — November 23, 19—

Except in writing very short letters, you should single-space each of the elements of the letter, and as a rule double-space between elements and between the paragraphs of the body. This means that the lines of the heading, inside address, and so forth, are single-spaced but that there is double spacing between the heading and the inside address, between the inside address and the salutation, between the salutation and the opening paragraph of the body, between paragraphs, and between the text and the complimentary close. The rule is not a hard and fast one, however; in order to ensure that the letter-block is of pleasing proportions on the page, you may need to triple-space, or more, between the heading and the inside address and between the last line of the body and the complimentary close. Quite short letters may be double-spaced throughout.

There are two commonly used styles of arrangement for the elements: the straight or full block form and the modified block form, and the only difference between the two is that paragraphs in the body are indented in the modified block form and unindented in the full block form. Full block form is illustrated in Figure 2, modified block form in Figure 1.

In the past it was common practice to use staggered indention for the elements, so that a heading, for instance, would look like this:

1919 South Second Street
Phoenix, Arizona
September 23, 19—

This style is scarcely ever used any more. Another style seen now and then is called the "left-wing" form: in it each element, including the heading and closing, is begun flush with the left margin.

Although the block form or the modified block form is entirely satisfactory for all formal business correspondence, there is a simpler and more convenient form for interdepartmental and personal communication within an organization. The memorandum form employs the principal features of the military correspondence form: "To," "From," and "Subject" headings printed on the stationery. In many organizations stationery of different colors is used, each department having a different color. Much less formal than the conventional letter, the memorandum is usually headed with a date, often expressed in abbreviated form such as 10/21/53, and simply signed or initialed at the end. Neither a salutation nor formal closing is needed.

Style and Tone

In regard to the style and tone of a business letter you should keep three facts in mind: it is a personal communication, it serves as a record, and it is usually brief.

Since a letter is a personal communication, almost always addressed to a specific individual, it should be characterized by courtesy and tact. In a sense, a letter is a substitute for a conversation with the person you are writing to, and you should, therefore, try to be as polite and considerate in your letter as you would be in dealing directly with the addressee. This consideration of the addressee, commonly called the "you attitude," will naturally suggest that your letter should not only be perfectly clear in meaning but also free of any statements which might needlessly antagonize or irritate the reader. The "you attitude" thus has two aspects: the general one suggested by the phrase "tact, courtesy, and consideration"; and a mechanical aspect.

To be truly considerate of the reader you need to grasp his point of view. Try to anticipate questions he might ask, and to estimate his reaction to your statements. You should examine your sentences to see if they are free of ambiguities, free of words the reader might not understand—in short, to see if the letter will say *to the addressee* what you want it to say. It is important to try to read it from the point of view of the addressee because you know what you intended to say and are likely to take it for granted that the words express your intention unless you critically examine everything you have written.

In a more mechanical sense the "you attitude" means substituting the second person pronoun ("you") for the first person ("I" or "we"). Use of the second person has the effect of keeping attention centered on the reader rather than the writer and thus helps to avoid any impression of egotism. Suppose a writer has made the following statement in a letter:

> I have noticed that your shipments to us have consistently been delayed. We are inconvenienced by these delays and request that you investigate the matter at once.

This rather blunt statement could have been better phrased as follows:

> I am writing to inquire about the cause of the rather consistent delay in the receipt of shipments from your company. You will understand, of course, that delay in receiving these shipments is the cause of considerable inconvenience to us and, we are sure, you will want to correct the situation as soon as possible.

Perhaps we should add that personal pronouns are entirely suitable to personal communication. Do not hesitate to use either "I" or "you" when it is natural to do so. Expressions like "the writer" instead of "I," or "it will be noted" instead of "you will notice" are out of place in correspondence. Be direct and natural.

In addition to being considerate, courteous, and unaffected in style, the letter should be concise. One of the conventions of the business world is that time is precious. Accordingly it is generally said that if at all possible a letter should be held to a single page. We subscribe to this view too, but with reservations. Do not make the mistake of believing that brevity alone is a virtue in letters. Too much brevity makes for a letter of very unsatisfactory tone. Carried too far it results in a curtness and bluntness which can be irritating. A further danger of carrying brevity too far is that it may result in a lack of clarity and completeness.

The fact that letters are filed as a record for possible future reference makes it desirable that a letter be clear and complete, not only at the time of writing but also at any later time at which it might prove necessary to look at the letter again. This need for clarity of reference is one reason why most letters of reply begin with a concrete reference to the date and subject of previous correspondence. It also explains why phrases like "the matter we corresponded about last month," are not satisfactory.

Types of Letters

In books which are devoted exclusively to letter writing, a great many types are discussed which we shall not have space for here. Should you need information about such types as claim and adjustment letters or sales letters, consult one of the volumes listed in Appendix A. Our discussion will be limited to five frequently used types of letters: inquiry, reply, instructions, transmittal, and application.

LETTERS OF INQUIRY AND REPLY. A good letter of inquiry should (1) identify the nature of the inquiry at the very beginning, (2) state the reason for the inquiry if it is not obvious, (3) clearly and explicitly phrase the inquiry so as to make reply as easy as possible, and (4) close with an appropriate and courteous statement.

Since anyone reading a letter naturally wants to know what it is about right away, the writer should state in his opening sentence what he is writing about. This does not mean that the salutation must be followed immediately by the specific inquiry or inquiries. It means that the purpose of the letter should be identified immedi-

ately as an inquiry about a specific subject. Thus you might begin, "I am writing this letter to inquire whether you have any new performance data for release on the ramjet engine you are developing." This statement could then be followed by concrete, specific questions.

Explaining the reason for making an inquiry is not absolutely necessary unless a response to the inquiry you are making constitutes the granting of a favor. It is always courteous, however, to explain why the inquiry is being made, and when you are definitely asking a favor, it is a courtesy that should not be neglected.

It is exasperating to receive an inquiry that is phrased in such general terms that no clear notion of what is wanted can be determined. Too often one sees statements like this: "Please send me what information you have on television antennas." The writer of this request probably wanted far less information than it seems to call for. Actually, his inquiry would have had more meaning had it been rephrased:

1. What types of television antennas do you manufacture?
2. Can you send me installation instructions for the types you manufacture?

Concrete, specific questions make a reply easier to write. Questions do not necessarily need to be numbered and listed as above, but such a form is perfectly satisfactory, and is desirable when several questions must be asked. Remember that vague, general requests may present an impossible problem to the man who receives the inquiry. We recall a student who wrote a request to a research organization for "any information you have about new aircraft designs" being worked on by the organization. Obviously he did not realize that a literal granting of his request might result in his receiving a truckload of reports! The problems of concreteness and courtesy are both well illustrated by the case of a graduate student of chemical engineering who wrote for some information to be used in one of his courses. The letter he wrote is quoted below, the only change being the deletion of names.

Dear Sir:

It is requested that literature concerning the history and background, wage and benefit plans, and general research policy of [your] Corporation, and a current statement to stockholders be sent to me at the above address.

This information is to be used in a report assigned in a graduate chemical engineering course. Additional information which you may have available will be appreciated.

This literature will be made available to the University Library after I have finished with it.

Any information you supply will be greatly appreciated.

Very truly yours,

The first paragraph of the reply received by the author of the above letter went as follows:

Dear Mr._______________:

We are glad to comply with your rather blunt request that we supply you with a great deal of not altogether inexpensive material to be used in a report in a graduate chemical engineering course. Since you are going to give it to the library after you have finished with it, we are less critical of the tone of your letter than we might otherwise be. I speak this way to bring to your attention something which may be useful to you later on, since believe me your letter of March 29 could be couched in more gracious terms.

The difficulty about this letter of request probably is to be attributed in the first place to the use of the passive voice. The phrase, "It is requested that . . ." is ungracious. Perhaps, "I am writing to ask if you could help me . . ." would have been more cordially received. In the second place, a comment on the kind of report that had to be written would have been useful in deciding what materials should be sent. The letter should have been rephrased throughout, particularly to indicate the writer's realization that he *is* asking for a great deal of help.

Custom suggests that letters of inquiry, especially those in which a favor is asked, close with a statement showing that their writers will appreciate a reply. This is adequately illustrated in the letter quoted above. But remember that good taste suggests that you avoid ending your letters with "Thanking you in advance, I remain, ..." If you are in a position to do so, it may be appropriate to offer to return the favor.

In writing a reply to a letter of inquiry, keep these two points in mind: (1) begin your letter with a reference to the inquiry, preferably both by date and subject; and (2) make the reply or replies as explicit and clear as possible. If the inquiry contained itemized questions, it is a good plan to itemize answers. Naturally, the reply should be courteous.

THE LETTER OF INSTRUCTION. When circumstances make it necessary for instructions to be issued by letter rather than by word of mouth, you will find the following plan of organization suitable:

1. The opening paragraph of the letter should explain the situation or problem which necessitates issuing the instructions.

2. The body of the letter should contain the detailed instructions. Common sense will tell you that these instructions should be clear and definite. Vague and ambiguous instructions often defeat their own purpose by confusing and irritating the reader and by making it less likely, consequently, that they will be satisfactorily carried out.

3. The conclusion of the letter should suggest any action, other than carrying out the instructions, that should be taken. This may be a request for a report, a conference, or the like.

THE LETTER OF TRANSMITTAL. The letter of transmittal is a communication from the writer of a report to its recipient. In a general way, it serves about the same purpose for a report that a preface does for a book. Although letters of transmittal are occasionally sent through the mails separately from the report itself, it is more common for them to be bound in with the report, following the title page. We shall discuss the five primary functions of a letter of transmittal in the sequence in which they usually appear.

1. The letter typically opens with a reference to the occasion of the report or a comment on why the report is being submitted. There may be a reference to a contract or other authorization of the work being reported on.

2. The letter should state the title of the report being transmitted. Both of these first two functions are illustrated in the following sentences:

> In response to your request, dated October 26, 19—, I have investigated the possibilities for a new plant location in the Southwest. The accompanying report, entitled *Advantages and Disadvantages of Five Southwestern Cities as Sites for a New Assembly Plant*, is an account of this investigation and the conclusions it led to.

3. The second paragraph of the letter of transmittal should explain the purpose and scope of the report (unless the opening paragraph has already done so). Beyond this, it should be devoted to any comments about the report that the writer feels should be made to the addressee. It might happen, for example, that the writer had on a previous occasion said that the report would contain information that was finally omitted. This omission should be explained.

Do not hesitate to duplicate, in the letter of transmittal, elements that also appear in the abstract or the introduction to the report. A statement of purpose, for instance, almost always appears in all three places.

5127 Clearview Street
Austin, Texas
November 20, 19-

Professor John C. Doe
Department of English
University of Texas
Austin 12, Texas

Dear Professor Doe:

The accompanying report on joistile-concrete beams is submitted in accordance with your instructions of October 10.

The primary purpose of the report is to present information about joistile-concrete beams for use in floor and roof constructions. An effort has been made to cover the subject thoroughly, including the development of joistile, its use and application in beams, investigations and tests of both joistile and joistile-concrete beams, and general specifications for the construction of tile-concrete beams and floor slabs. The section on investigations and tests is limited to the most important and pertinent tests and results.

I wish to acknowledge the information and assistance given me by Mr. James Wood of the Greek Key Ceramics Association.

It is sincerely hoped that this report will meet with your approval.

Respectfully yours,

Richard Roe

Richard Roe

Fig. 3. Letter of Transmittal

4. If the writer has received assistance in carrying out the work with which his report is concerned and feels that this assistance should be acknowledged, the letter of transmittal is a place in which he can name and thank those who helped him.

5. Customarily the letter closes with a statement expressing hope that the report is satisfactory.

The five functions that have been mentioned are illustrated in Figure 3.

THE LETTER OF APPLICATION. Most students properly feel that no form of the business letter is as important to them as the letter of application for a job. We shall accordingly discuss this type of letter in considerable detail.

Since the amount and variety of information an employer will want to know about you is great, it is ordinarily impracticable to attempt to include it all within the framework of the conventional business letter. We will, therefore, consider that form of application which is made in two parts: (1) a data sheet or qualifications record, and (2) an accompanying letter. We shall discuss the data sheet first since what is said in the letter will depend, to some extent, upon what is included on the data sheet.

1. *The Data Sheet.* The data sheet contains about the same information called for on most printed application forms, organized in four sections:

A. Personal data
B. Education
C. Experience
D. References

The form of a data sheet is illustrated in Figure 4B.

The personal data section should contain enough information to enable an employer to get some idea of what you are like personally. Individual headings may include age, place of birth, health data (height, weight, eyesight, and hearing), nationality, marital status and dependents, religious preference, recreational interests, organization and society memberships.

Accompanying these data and placed in the upper right-hand corner of the sheet should appear a photograph. Of regulation size (any commercial photographer will know about this), the application photograph should be a perfectly straightforward, unretouched serious pose. The "portrait" type of picture, such as you may have had made for gifts, is not appropriate. Naturally the photograph is of interest to any employer because he wants to know what you look like.

5127 Clearview Street
Austin 3, Texas
June 14, 1949

Mr. M. A. Smith, Head
Personnel Department
Rhode Island Oil Company
Sarnia, Texas

Dear Mr. Smith:

I talked to your Austin representative, Mr. Clapper, and he informed me that it is a policy of your Company to employ college students of petroleum engineering each summer as assistant gaugers. I should like to submit my application for that position.

While working with the Marshall Drilling Company I became thoroughly familiar with the location of wells on your Chalker and Sarnia fields. In fact, I happened to be working with the crew that drilled the first deep dual-completion well on the Dole lease last July. The course which I completed this year in Petroleum Production covered production gauges and their functions and operation quite thoroughly.

Please refer to the enclosed data sheet for details of my education and experience and the names of persons who have consented to express an opinion about my ability and character.

I shall be glad to go to your Sarnia office any Saturday on a few hours' notice. My schoolwork makes it virtually impossible for me to go during the week.

Yours respectfully,

Richard Roe

Richard Roe

Fig. 4A. Letter of Application

DATA SHEET

Richard Roe
5127 Clearview Street
Austin 3, Texas

Personal Data, June 1951

Age 24
Height 5 ft, 8 in.
Weight 155 lb
American
White

Protestant
Married
Health excellent
Eyesight good
Hearing good
Veteran

Education

Leaton High School (Texas), 1942
A.A.F. Pilot Training (1944)
Junior Classification in Petroleum Engineering
in The University of Texas
Important Courses:
Calculus
Descriptive Geometry
Machine Design
Engineering Drawing
Physics

Chemistry
Statics
Petroleum Production
Petroleum Exploitation

Experience

Summer of 1948
"Roughneck" on oil drilling rig under Mr. John C. Doe, Marshall Drilling Co., Sarnia, Texas
Summer of 1947
Assistant "Shooter" on explosive truck under Mr. James Stone, United Geophysical Co., San Antonio, Texas
1944-46
Transport pilot Army Air Forces

References (by permission)

Mr. Joseph Wood, President
Chamber of Commerce
Sarnia, Texas

Mr. James Stone, Manager
United Geophysical Co.
San Antonio, Texas

Professor Howard Bitt
Department of Petroleum Engineering
College of Engineering
The University of Texas
Austin, Texas

Fig. 4B. Data Sheet

We believe one should be included with every application. We do know, however, of one interesting instance in which an applicant purposely left his out. As a matter of fact, he made a point of referring to its omission in his letter and explained it by remarking that he was undoubtedly the ugliest man living. Since the prospective employer was impressed by the man's qualifications and curious about this comment on appearance, he invited him to an interview and hired him. He said later, though, that the man's remark was correct—he was the ugliest man he'd ever seen.

In an application from a man with several years' experience, the section on education scarcely need contain more than the fact that the applicant received a degree at a certain place and time. Experience, or what he has done, is what will be of interest to an employer. But for the young man, especially the one just completing his training, the section on education is most important. Education is what the young man has to offer. He should make the most of it in his application by giving full and complete details about all of it that is pertinent to the job applied for. He should state in this section the name of his high school and the date of graduation; the name of his college and the date, or expected date, of graduation; the degree he has, or is seeking; his rank in his class; his major and minor fields; and a list of the courses pertinent to the requirements of the position sought. It may be desirable to give the number of credit hours earned in each course. Some applicants prefer to classify courses as basic, specialized or technical, and general, but this is not necessary.

Sometimes an applicant feels that giving an employer the information that he has a B.S. degree is enough. But programs differ a good deal from one college to another. It is better to call attention to the courses you feel help qualify you for the job. Do not, of course, name those subjects which cannot possibly qualify you for the particular position you are trying to get. You will not need to list the same courses in every application you make, though there will naturally be a considerable amount of duplication.

Although the young graduate may have had little or no experience related to the kind of professional work he is seeking, he should nevertheless record the facts about any jobs he has held, including part-time and summer jobs. Many an employer will be interested in finding out how well an applicant has discharged responsibility and how diligent and cooperative he has been in carrying out duties and working with other people, for he may believe that a man's attitude toward his job and the people with whom he works is not likely to change, regardless of the nature of the work.

List the most recent jobs first and work back chronologically. For each job give (a) the dates of employment, (b) the kind of work done, (c) the name of the person who would be qualified to evaluate your services, (d) the name of the company or organization, and (e) its address. Be sure to record the name of your superior and the name and address of the company accurately so that an inquiry will be certain to reach its destination.

One sometimes hears it said, "It's not *what* you know that gets you ahead; it's *who* you know." We do not subscribe to this cynical remark but neither do we wish to minimize the importance of having influential people back you up in your application. Often the recommendation of a man whose word is respected is the deciding factor in getting a job. This is perhaps especially true when an employer is considering a number of applications from graduates who do not have professional experience. The academic records alone might not provide a clear basis for a choice. We believe you should devote careful thought to this matter of references and make the most of your opportunities.

At least three and perhaps as many as five references should be listed. One of these should be an employer, if possible; one should be a person who has known you personally a long time and who can therefore vouch for your character; and the others should be those of your teachers who can vouch for the quality of your work as a student. Be sure to get permission from each one before giving his name. It's a good plan to tell each reference, at the time you ask his permission, something about the job you are applying for so that he can write a better letter of recommendation for you, one in which he can emphasize qualifications which are pertinent to the job you are after. Be very sure that you do your references the courtesy of spelling their names correctly, and for your own sake be sure to give an address by which they can be reached.

One final word about references. If you are especially eager to get the job you are applying for and feel that you can presume upon the kindness of some of your references, ask them to write unsolicited letters of recommendation, to be sent so that they will be received shortly after your application has been received. This support for an application may be quite effective, and it is comforting to know that a recommendation has been made. A prospective employer may not take the initiative by writing for information about you. We know of one young applicant who went a step further; he asked one of his references to put in a long-distance telephone call in his behalf. He got the job too.

2. *The Letter.* The letter accompanying a data sheet has four principal functions to perform: (a) making reference to your source of information about the opening, (b) explicitly making application for a job, (c) elaborating on pertinent qualifications, and (d) requesting an interview. These functions are illustrated in Figure 4A.

If some person, like a company representative or employee, has told you of an opening, the best way to begin your letter is by making reference to that person by name. Seeing a familiar name, the employer is likely to continue reading and to give your application consideration. If your source of knowledge is an advertisement, refer to that. If you do not know whether an opening exists or not, you may begin by mentioning your interest in getting into the particular kind of work done by the company, or your desire to be associated with the company, as your reason for applying. Openings which stress an interest in a particular company must be tactfully written so they will not sound as if flattery is being employed to gain a sympathetic hearing.

Explicitly stating that you are applying for a job is more than a conventional formality; it permits you to state exactly what work it is that you are after. Applying for a specific job is always better than just asking for employment, and this is particularly true when you are applying to a large corporation in which many technical men are employed in all sorts of jobs, jobs which do not always bear a direct relationship to the academic training of those who fill them. This emphasis on making applications for a specific position may seem to ignore the fact that many graduates are put into a training program upon first being employed by a large organization. If you know that the company you are applying to puts all newly hired men into a training program, make your application for a place in that program and state what your particular professional interest is, too.

The first paragraph of the letter, then, contains at least the second and perhaps both of the following two elements: (1) a reference to your source of information about the job that is open, and (2) a statement about what job you want. The next paragraph (or paragraphs) is the hardest to write—and the most important. It is the real body of your letter; it is here that you distinguish your application from others. In it you may single out for detailed discussion something from your training or experience that particularly qualifies you for the job you are trying to get.

Remember that the data sheet gives the bare details. A mechani-

cal engineer, for instance, may have listed a course in machine design on the data sheet made for an application to a company for a position in a tool and die design department. But merely naming the course does not tell what the engineer did in the course, or whether he did well or poorly. Suppose he had undertaken several projects and completed them successfully and suppose he has learned that this experience will help him if he gets the job. He will do well, then, to provide the employer with the details about this course and the projects he completed. Similarly, merely naming a job on the experience record scarcely does more than suggest the duties, skills, and responsibilities that the job demanded. The letter gives you an opportunity to provide full information about those aspects of your training and experience which best fit you for the job you are after.

You must, of course, carefully analyze the job's requirements and measure them against your own qualifications before selecting something to write about. It is this elaboration of selected details of your qualifications which makes your letter something more than a letter of transmittal for your data sheet. These details about your training and experience make your qualifications for a job obvious to an employer. One final caution: do not state that you feel you are fully qualified for the job unless you supply information enough to support such a claim. And if you have presented the support, it is hardly necessary to make the claim. After all, very few graduates are fully qualified for any job until they acquire some experience.

Since the immediate objective of a letter of application is conventionally assumed to be an interview, you will probably want to close your letter with a request for one. You should take pains to phrase this request so that it will convey the idea that you are interested in having the interview, not merely willing to have it. Accommodate yourself to the employer's convenience so far as possible. Suggest that you will be glad to appear at a time convenient to him. If there are restrictions on your time which make it impossible for you to be interviewed at certain periods be sure to state what they are and explain them. If time and distance make it impossible for you to go to an employer for an interview, explain the facts, express your regret, and suggest an alternative, such as being interviewed by a company employee in your vicinity.

If you receive no response from your application within a reasonable time, you may find it helpful to write a follow-up letter. In this letter you may inquire whether your application has been received and thus remind the employer of it. If possible, it is a good idea to add

some new support to your application. This may be presented as a sort of afterthought. Sometimes the follow-up letter is just what is needed to secure you that extra consideration that results in a job.

Conclusion

If you hired a man to act as your personal representative you would want him to be pleasing in appearance, businesslike and alert in manner, and urbane and intelligent in speech. A letter is your personal representative. Don't be satisfied with inferior specimens. This chapter will give you a start toward good letter writing. A book on the subject will help you further. Intelligent practice will help you the most of all.

Suggestions for Writing

1. If you are writing a library research report for your course in technical writing, you might attempt to supplement the library materials available by writing to several companies for information not obtainable in the library. Be sure, if you write such an inquiry, to explain why you are making it.

2. Write a letter of application, together with a data sheet. To get the most benefit from this exercise, you should make the application as realistic as possible: aim it at a job your present experience and training qualify you for. A summer job is a suggestion.

3. When reports are required, write letters of transmittal for them.

18

Writing for Professional Journals

Publication of articles in professional journals may benefit your career in many ways. Such publication is likely to increase your circle of professional acquaintances; it is certain to put an example of your work in the hands of leaders in your field; and it will be a strong stimulus toward mastery of your area of specialization. It may also have a more direct effect on your advancement, for many firms strongly encourage their employees to publish.

Publication of semitechnical articles in popular magazines also has attractions—mostly monetary. Technical journalism of this sort interests only a small minority of scientists and engineers, however, and for that reason we shall not discuss it here.*

The professional journals—by which we mean loosely any journal whose readers include only trained specialists—do not ordinarily pay for contributions. It is nevertheless by no means always easy to place

* If you are interested in this field, see E. Brennecke, Jr., and D. L. Clark, *Magazine Article Writing* (New York, 1942).

an article with them. Usually these journals have many more articles submitted to them than they can possibly publish. You should not be surprised to have your offering flatly rejected, or to have it returned with a request for revision. And you should not assume that a rejection indicates that you have written a poor article; an article may be turned down for a number of reasons which have nothing to do with its quality. It may be concerned with an area which the editors feel has already been given all the space in recent issues that they can devote to it; it may be presented in a way that the editors feel would not interest their readers, although it might interest other readers (in this case they are likely to suggest another journal or journals to you); or it may be an article that at another time would have been accepted but which is now rejected simply because the editors have on hand a large number of unprinted articles of high quality. And frankly, an article from an unknown engineer is less likely to be accepted than one bearing the name of a man with a nation-wide reputation. But don't assume that a man without a reputation should abandon hope: nothing could be farther from the truth. If you have something significant to say, and say it clearly, you are almost certain to have your work published. Just don't forget the virtues of patience and common sense.

In this chapter we shall discuss the problems of choosing a subject, selecting a journal to send your article to, writing the article in a suitable style, and putting the manuscript into the proper form.

There are obvious limitations to what we can say about the choice of a subject for an article. In fact, it is often difficult to say whether, in practice, a person selects a subject because he wants to write an article, or wants to write an article because he has a subject. Ideally, the latter would always be true. Publication would be considered only when a person's thinking and research had developed facts or theories which he realized might be of value to other workers. A famous fictional presentation of this ideal, and a satire of its opposite of seeking fame through shoddy, pretentious, over-hasty publication, is Sinclair Lewis's *Arrowsmith*. But, as Lewis said too, human motives are seldom unmixed. Granted honesty and sincerity, there is little point in thinking much about whether desire for publication or interest in a subject comes first. In any case, there isn't much we can say here about your personal interests.

The only advice we can give here about how to find a subject, in contrast to evaluation of a subject, is to read widely in your field, to acquire a wide acquaintance among your colleagues, to attend meetings of professional societies, and everywhere to use your imagi-

nation and to be critical. Be slow to assume that an explanation is correct, or that a method is the best method. Out of such an attitude will come new ideas for research and publication.

When you have an idea that looks interesting, work at it. We once heard a well-known physicist say that one of the chief differences between creative and noncreative men in his field was that the noncreative men simply failed to develop their ideas. A good deal of determination and some stubbornness are called for. Do your own thinking, and allow in advance for opposition to new ideas. But be sure to distinguish between boldness in conceiving new ideas and carelessness in developing them. You should be patience itself in calculating, testing, checking, and criticizing an idea once you have gone to work on it.

It is wise to keep a file of possible subjects for investigation. Here are some questions to ask yourself in evaluating subjects for your file.

1. Is development of the idea within your present ability? Of course you will want to add to your knowledge and skills, but don't take on too much at once.

2. Is equipment available to you for the work that will be required?

3. Do you feel a real interest in the subject? Don't let circumstances coax you into work you don't care for when you could be doing something you'd like.

4. Will the subject open up further possibilities of research and publication, or is it a dead end?

5. Is the subject in a field that has received little recognition? Or is the subject in a field that is overworked? Either possibility may mean difficulty in getting your article published and the merits of your work recognized.

6. Will work on the subject contribute to your ability and success in the kind of career you desire? An article on the nerve fibers of the squid would probably do little to further the career of a civil engineer.

Such considerations as the foregoing are very much worth your attention before you commit yourself to any project that will take more than a few days of your time.

Having decided to write an article, you must begin thinking about where to send it. The first step is to find out what journals publish material of the kind you will have. Of course you should be acquainting yourself with such journals anyhow; familiarity with them is an important part of your professional equipment. (For guides to help you locate the journals in your field, see Chapter 21.)

A second step is to analyze the journals you have decided are possible targets. Can you find any articles in them, dating from the last year or two, which are on a subject comparable to yours? You needn't feel that you should find exactly the same subject, and of course you shouldn't expect to find an article that says approximately the same thing that you are going to say. This possibility of duplication, incidentally, brings up another matter. You should be very careful to look at every article that has been published anywhere on your specific subject, no matter how tedious the hunt may be, to make sure that you are not merely repeating somebody else's work, as well as to inform yourself fully on your subject.

When you have a list of the journals that show an interest in the kind of subject you have, it is wise to make your next step a conference with a man who has had considerable experience with professional publication. Your boss or your college instructor is a good possibility. As a matter of fact, it is possible that your boss or your college instructor is one of the editors of a professional journal. At any rate, try to talk over your whole project with someone who can give you practical advice. You may acquire invaluable information about editorial whims, possible places to publish the article, and the like. It is not uncommon for a beginner to achieve his first publication through the friendly help of an older, well-known man whose recommendation carries weight.

Next, you should analyze the style of the journal you have chosen. This analysis involves two elements—literary style and physical format.

Literary style is perhaps less important in a professional journal than in a popular journal, where appeal to a large, untrained audience demands a vivid presentation. Nevertheless, it is well worth your time to see if there are any special preferences or prejudices in regard to style and general attitude that examination of numerous issues of the journal will reveal. Is the treatment theoretical or practical? Speculative or down to earth? Informal and colloquial, or formal and restrained? You will probably find considerable variety even within a single issue, but usually a fairly definite tone will become evident as you read through several issues. Try to get the feel of the journal, and write your article accordingly. Remember that editors are human beings, and the problem of reader analysis is essentially the same in writing for an editor as in writing a routine report in college or on the job. All you know about the editor, however, may be what you can infer from analysis of the articles he has chosen for publication. As a matter of fact, articles are usually read by several

people, usually two or three besides the principal editor who is responsible for the final decision.

Analysis of the physical format (form of footnotes, subheads, and the like) preferred by a journal is a simpler task than analysis of the literary style. Very often specific directions are available, and when they are not, the form of articles printed in the journal serves as a model. Some professional societies that publish journals issue pamphlets giving instructions on form. Some journals regularly print short statements about form. Examine closely the journal you are interested in, and if you find no hint of directions to be followed, pick out two or three articles and use them as models. Note particularly such matters as use of subheads, footnote and bibliographical forms, whether or not an abstract is used (and if it is, what type it is), types of illustrations, how numbers are written, what abbreviations are used.

Your article will of course be typed, preferably with pica type, and double-spaced. You should make at least one carbon copy to keep for yourself. Some journals request that two or three copies of a manuscript be submitted so that the several editorial readers will not have to wait on one another. Good clear carbons are acceptable, and—in the carbon copies—illustrations can be roughed in, or if that is not feasible a brief explanatory note can be substituted.

Here are some general suggestions about manuscript form.*

1. Use good paper of standard size (8½ by 11 inches).

2. Leave a margin of 1¼ inches at the left and one inch on the other three sides of the page.

3. Type your name and address in the upper right-hand corner of the first page.

4. Type the title of the article about halfway down the first page. Underneath, type "by" and underneath that your name, triple-spaced, like this:

ELECTRONICS

by

John Doe

* For more detailed instructions see Sam F. Trelease, *The Scientific Paper* (Baltimore, 1947).

The empty space in the top half of the page is a convenience to the editor for making notes.

5. In the upper right corner of each page after the first page type the title of the article, followed by a dash and the page number. If the title is long, use an abbreviated form of it.

6. There are various ways of handling illustrations, but if you have no specific directions the following will be satisfactory. First, be sure you have put a clear title on every illustration (photographs, drawings, charts, graphs—and also tables) and, if there are several illustrations, a figure number. Next, instead of putting the illustrations into the text, collect them in an envelope at the end of the manuscript. To show where they go in the body of the text, write the figure number and the title in a blank space left in the appropriate place in the text. Finally, add to the collected illustrations a typed list, on a sheet 8½ by 11, of figure numbers and titles (this sheet should not have a page number). Further suggestions on illustrations will be found in Chapter 20, and further suggestions on manuscript form in Chapter 19. Incidentally, remember that reproduction of illustrations is relatively expensive, and professional journals do not always have an abundant supply of money.

7. Proofread your manuscript with great care, particularly tables and graphs. This job is dull and time-consuming, but it is imperative that it be well done. Ask a friend to read aloud from the rough draft while you check the final copy. A page on which numerous corrections must be made should be retyped. If there are no more than two or three corrections on a page, however, it is permissible to make them neatly between the lines.

8. Mail the manuscript flat. Enclose some kind of stiffener, like heavy cardboard, if there are illustrations that would be seriously damaged by folding. It's a good idea to mark the envelope "Do Not Fold." Include in the envelope a self-addressed stamped envelope to bring back the manuscript if it is rejected.

9. Resign yourself to a long wait. You may learn the fate of your manuscript in six weeks, but it may take six months. If you've had no word in six months an inquiry would not be out of order.

If your manuscript is rejected mail it out again at once. But there are two things that should be done first. One is to make sure that the manuscript looks absolutely fresh. An editor is never flattered by a suspicion that his office isn't the first your manuscript has visited. The second thing is to consider whether any changes should be made in the article to adapt it to the policies and attitudes of the

journal you now have in mind. You should be as careful about this on the second, third, or fourth mailing as on the first.

Of course your manuscript may be accepted the first time out, or it may come back with a request for revision. Whether or not to revise as requested is a matter to be settled between you and your conscience. Chances are that the editor is right. If you think he is wrong, and feel strongly about the matter, it may be better to seek publication elsewhere. In any case, don't be fussy about little things. Few editors can resist changing a few commas, at least.

When your manuscript has been accepted, there will probably arrive, in due time, some "proof sheets" or "galley proof." These are long sheets of paper on which the printed version of your article appears. Your job is to proofread these sheets and return them to the editor. You should again get someone to assist you.

Corrections on proof sheets should be made with standardized "proofreader's marks." These marks, together with directions for their use, can be found in most good dictionaries. With a few exceptions corrections should be made only of errors that the printer has committed, because of the expense involved in resetting type. On the other hand if you discover that you have overlooked glaring errors in grammar or in facts you should certainly correct them.

You may or may not later on receive the corrected proof sheets to examine. If you do, the checking process should be conducted as meticulously as before, but—with very rare exceptions—only printing errors should be corrected.

Writing an article for publication in a professional journal is fundamentally like any technical writing. The principles of reader analysis, logical organization, and clarity of expression must be observed. There are some special problems involved: selection of a subject, choice of a journal to submit your article to, handling of the manuscript, and correction of the proof sheets. But these are all problems that can be solved by a methodical approach. Be bold in your plans, and painstaking in their execution. And, in the end, you will find it pleasant to remark casually to your friends, "As I pointed out in an article I published in . . . ."

section five

Report Layout

The two chapters in this section are concerned with the format of reports and with graphic aids, respectively. The subject of format includes in general the "mechanics" of report preparation, like the arrangement of a title page or the placement of subheads. The term "graphic aids" refers to any nontextual device included in a report, like a photograph, a table, or a chart. The subject matter of the two chapters differs in many respects but is similar in that both chapters are involved with the problem of visual effect.

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The Format of Reports

Introduction

If you were to examine carefully the format of reports prepared by engineers and scientists in the employ of a representative number of companies and organizations and at the same time read the instructions these companies and organizations issue on the preparation of reports, you would observe that (1) all companies do not use the same format, although the differences are likely to be minor ones of detail, and (2) all the companies and organizations agree that attractive format is necessary.

While accuracy and clarity are always of paramount importance, you need to remember that a report makes an impression on its reader even before he has an opportunity to determine whether its contents are accurate and clear. We once heard a well-known engineer tell a story of visiting an industrialist's office and seeing the industrialist pick up a handsomely bound report just as it was delivered to his desk, leaf through it, and remark that it was a fine job of engineering report writing. He hadn't read the report; he made this judgment solely on the basis of its appearance.

Common sense will tell you that it pays to make your reports look good. The question is not whether attractive format is desirable, but what *is* attractive format. The following pages, therefore, will be devoted to a discussion of typescript standards and the form of the elements of a report, plus some notes on the relationship of form to organization and style. We want to say, before presenting the "rules" which follow, that no body of rules exists for report format which could be regarded as authoritative the country over. The ones we present are representative of good practice, however, and will be acceptable whenever you do not have other instructions.

Typescript Standards

When you prepare a typewritten report, you will have to make decisions regarding the choice of paper, width of margins, spacing and indenting, and paging.

PAPER. Reports should be typewritten on white paper of high quality, preferably 20-pound bond, 8½ by 11 inches in size. Second sheets, if carbon copies are to be made, should be of high quality, rag content white bond, about 13-pound weight. A good quality paper is essential if a neat, attractive copy is to result; inking and erasures, for instance, require good paper. Always use white paper unless you have instructions to the contrary. Some companies use colored sheets to identify certain types of reports or reports from certain departments.

MARGINS. Margins for the typewritten report should be approximately as follows:

Left Side	*Top*	*Right Side*	*Bottom*
1½"	1"	1"	1"

Since the left-hand margin must be wide enough to allow for binding, up to two inches may be needed, depending upon the nature of the binding. No reader likes to be forced to strain the binding or his eyes in order to read the words on the bound side of the sheet. The right-hand margin cannot, of course, be kept exactly even on account of the necessity of dividing words properly, but an effort should be made to keep a minimum margin of ¾ inch.

Where quotations are introduced into the text of a report, an additional five spaces of margin must be allowed on the left side and approximately that on the right.

SPACING AND INDENTING. The text of a report should be double-spaced throughout, except as noted below:

1. Triple- or quadruple-space below center headings.

2. Single-space and center listings (if items are numerous, number them).

3. Single-space long quotations—those which run four or more lines in length.

4. Triple-space above and below quotations and listings.

5. Single-space individual footnotes more than a line long; double-space between notes.

6. Single-space individual entries in the bibliography; double-space between entries; use hanging indention in bibliographical entries of more than one line in length.

7. Single-space the abstract if space demands it; otherwise, double-space it.

8. Usually, single-space material in the appendix.

9. Double-space above and below side headings.

The customary indention at the beginning of a paragraph is five spaces. An additional five spaces (or more if necessary for centering) should be allowed before beginning a listing. As noted in the preceding section, five additional spaces of margin are necessary in giving formal quotations.

PAGING. Pages should be numbered with Arabic numbers in the upper right-hand corner, except for prefatory pages and the first page of the body (see below), and pages which begin new divisions. The number should be in alignment with the right-hand margin, at least two spaces above the first line of text on the page, and about ¾ inch down from the top edge. The prefatory pages of a report—title page, letter of transmittal, table of contents, list of figures, and abstract—should be numbered with lower-case Roman numerals, centered at the bottom of the page, about ¾ inch from the bottom edge. It is customary to omit the numbers from the title page and the letter of transmittal, although these pages are counted; thus the table of contents becomes iii. In the body of the report, it is customary to omit placing the number 1 on the first page since the title there obviously identifies it as page one. As for pages which begin main sections of the report, it is probably best to place the number in the bottom middle of the page. Pages of the appendix are numbered as in the body, in the upper right corner. No punctuation should follow page numbers.

Elements of the Formal Report

By formal report we mean the conventional "full dress" report, with all or nearly all of the parts which will be described below. Informal reports do not possess all the parts usually included in the formal report and thus present a somewhat different problem so far as format is concerned. Informal reports will be considered later in this chapter.

THE COVER. Ordinarily you will not have to worry about making up a cover for your report, for most companies have prepared covers. These are made, usually, of a heavy but flexible paper, with a printed heading naming the company and the division, and with a space for information about the report itself. This information consists of (1) the title, usually prominently displayed in underlined capital letters, (2) the report number, and (3) the date. Sometimes this information is typed on the cover itself, and sometimes it is typed on gummed slips and pasted on. In either case, the title should be clearly legible. Triple spacing between the lines of two- or three-line titles is advisable.

Occasionally the name of the client to whom a report is submitted and the name or names of its authors may be found on the cover, but as a general rule only the three items of information mentioned above are recorded. These serve to identify the report for filing and reference purposes; additional information may lessen the prominence of these important facts and detract from the attractiveness of the layout.

If prepared covers are not supplied, you can use a plain Manila folder or one of the readily available pressboard binders. An interesting and attractive innovation is the binder with a "window"—a rectangular transparency fitted into the cover so that the title of a report may be read directly from the title page.

THE TITLE PAGE. Besides duplicating the information found on the cover, the title page gives a good deal more. The most significant additional information presented here is the name of the person or persons who prepared the report and an identification of them as to position in the company or organization. In addition to authorship, the title page of reports from most industrial concerns provides space for the signatures of those who approve, check, and (sometimes) revise the report. Some companies provide space for "Remarks" of those who check the report. Finally it is not unusual to find a notation of the number of pages of the report. The accompanying illustration (Figure 5) is fairly typical. Note that the title ap-

REPORT NO.

NO. OF PAGES

McDONNELL AIRCRAFT CORP.

LAMBERT - ST. LOUIS MUNICIPAL AIRPORT

ST LOUIS, MISSOURI

ENGINEERING DEPARTMENT

AERODYNAMICS REPORT

FOR

McDONNELL MODEL 56 AIRPLANE

SUBMITTED UNDER CONTRACT

PREPARED BY APPROVED BY

CHECKED BY

DATE

REVISIONS

PAGES AFFECTED REMARKS

Fig. 5. Title Page: Example 1. Used by permission of the McDonnell Aircraft Corporation.

Report on

<u>Combating the Stall Problem</u>

Submitted to
Mr. John Doe
Director of Research
Wakey Products, Inc.
Detroit, Michigan

by
Richard Roe
Aeronautical Research Assistant

September 10, 1953

Fig. 6. Title Page: Example 2

pears in underscored capital letters, centered about one third of the way down from the top of the page.

Should you be required to write a report for a company which does not provide a prescribed form for the title page, you will find the model given as Figure 6 satisfactory. Note that it contains four elements attractively grouped and spaced. The title appears in the upper third of the sheet, underscored and centered, with triple spacing between the lines. Centered on the page appears information about the recipient of the report. On the bottom third of the page appears the reporter's name and professional identification; the last entry is the date of submission. In centering material on the page, do not forget to allow about half an inch for binding.

THE LETTER OF TRANSMITTAL. Since we discuss the letter of transmittal at length in another place (see Chapter 17), we simply want to point out here that this part of the report should be meticulously accurate in form and layout. While it usually appears immediately after the title page, some companies require that it appear as the first item in the report, just inside the cover (or even stapled onto the outside of the cover). Sometimes the letter of transmittal does not form a part of the report at all but is sent separately through the mails.

THE TABLE OF CONTENTS. The table of contents of a report is an analytical outline, modified in form for the sake of appearance. It serves as an accurate and complete guide to the contents of the report. The entries which appear in this outline also appear in the text of the report as headings; thus a reader may refer to a particular section or subsection of the report with a minimum of effort. It is imperative that every heading in the outline appear in the text as a heading or subheading; it is not necessary, however, that every subheading in the text appear in the outline.

Except for the Roman numerals for main division headings, the conventional outline symbols (A,B,C, . . . for subdivisions) are omitted in typing the table of contents, indention alone being used to show subordination. Omitting the capital letters and Arabic numerals results in a neater page. But although this is majority practice, it is by no means unanimous. Some companies retain all of the conventional outline symbols; some omit all of them. Whether they are retained or not, it is a good idea not to clutter up a table of contents with minute subdivisions: three levels are enough (this is not intended to suggest, of course, that your *plans* should not be detailed). Examine the accompanying examples.

You will note that all of the specimens have this in common:

Table of Contents

Fig. 7. Table of Contents: Example 1

Table of Contents

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Fig. 8. Table of Contents: Example 2

ABC LABORATORIES

PRODUCTS APPLICATION DEPARTMENT

GREASE AND INDUSTRIAL LUBRICANTS TESTING GROUP

DETERMINATION OF SUITABLE ROTOR BEARING GREASE FOR USE IN THE BROWN MAGNETO

INDEX

INDEX TO TABLES

INDEX TO FIGURES

Fig. 9. Table of Contents: Example 3

they provide plenty of white space so that the prominently displayed headings may be easily read and so that the page as a whole presents a pleasing appearance. For the best mechanical layout of the page, follow these suggestions:

1. Center and underscore "Table of Contents" at the top of the page. Use either capitals or lower-case letters.

2. Triple or quadruple space below the centered "Table of Contents." Double space between the items in the formal listing of contents. If there are numerous subtopics, they may be single-spaced.

3. Begin items preceding Roman numeral I flush with the left margin. These items include the List of Figures and Abstract.

4. Indent second-order headings five spaces, third-order headings ten spaces.

5. Use a row of periods to lead from the topic to the page number at the right margin, but stop three periods short of the page number.

6. After the last Roman numeral entry, list items in the appendix. Place the word "Appendix" flush with the left-hand margin, as shown in Figure 8, and indent the individual entries two spaces. The bibliography comes first. If nothing besides a bibliography is to be appended, do not use the word "Appendix": place the word "Bibliography" where the word "Appendix" would otherwise appear.

THE LIST OF FIGURES. If a report contains a half-dozen or more illustrations, drawings, exhibits or the like, an index to them should follow the table of contents. Usually called "List of Figures," this page gives the number, title, and page reference of each figure in the report.

The actual layout of the page is simple. Center the title at the top of the page (allowing for top margin) and underscore it. Triple- or quadruple-space before beginning the list. Figure numbers should be aligned at the left margin and followed by periods. The initial letter of each important word in the titles of figures should be capitalized. Page numbers should be aligned at the right margin, with a row of periods connecting title and number. Double-space between entries, but single-space an individual title requiring more than one line (and it should be remembered that a line should not be carried all the way over to the right margin). This spacing will allow for plenty of white space—a requirement for a neat, attractive page. See Figure 10.

There are, of course, some variants of this form. Some companies like to classify nontextual material so that there is, besides a list of figures, an index to tables, and perhaps even a list of photographs.

List of Figures

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Fig. 10. Layout of List of Figures

Separate pages are not needed for these separated listings, unless space requires them. Occasionally when the table of contents is quite short and there are few illustrations to list, both the table of contents and the list of figures may be placed on one page. Informal, short reports containing fewer than five or six illustrations usually omit a formal list. Custom in an organization will dictate whether omission of the list of figures is permissible.

THE ABSTRACT. The writing of an abstract is discussed in Chapter 4; here we shall state what is required for its format. The word "Abstract" should be centered and underlined at the top of the page. Allow triple or quadruple spacing after this title and then double-space the text of the abstract itself, maintaining the same margins as for the body of the report. In some cases, where space is at a premium, the abstract may be single-spaced, but double spacing is better.

You may have observed that the term "Abstract" is not universally used; some companies call this part of the report a "Digest," some a "Summary," some a "Foreword," and some an "Epitome." Whatever it is called, format requirements are the same.

HEADINGS. The topical entries of the outline table of contents are reproduced in the text of a report as headings to identify the individual portions of the subject matter. They serve as transitional devices and enable a reader to find a specific part of a report's discussion with ease. We are concerned with the form and location on the page of the three types: main or center headings, and two types of subheadings.

1. *Main or center headings.* Main headings name the major divisions (Roman numeral divisions) of a report. Written in either lower-case letters or capitals, a main division heading is underlined and placed in the center of the page, with the Roman numeral preceding it, as "I. Introduction." In formal reports, it is customary to begin new divisions of a report on a new page, just as a new chapter in a book begins on a new page. The centered title should stand a minimum of three lines above the first line of text of the division or the first subheading.

2. *Subheadings.* Usually only two levels of subheading are needed beyond the main headings: that is, headings corresponding to capital letter and Arabic numeral divisions, respectively, in the outline.

The capital letter or second-order headings should be placed on the left margin. Underline each word separately. Use lower-case letters but capitalize the initial letter of each important word. Double-space above and below the heading, and do not put any text on the same line as the heading. Don't put any punctuation after the heading.

The Arabic numeral or third-order headings should be handled exactly like the second-order headings with three exceptions: (1) indent the heading five spaces; (2) put a period after the heading; (3) start the text on the same line as the heading.

II. Circuit Elements and Transmission Lines

In order to understand the problems and principles of the operation of carrier circuits, it is first necessary to understand the characteristics of circuit elements and transmission lines at both power and carrier frequencies. The most common elements are resistors, capacitors, inductors, transformers and sections of transmission lines.

Circuit Elements

Different circuit elements have separate and distinct properties. Because of this difference, resistors, inductors, capacitors, and transformers will be considered separately.

Resistors. A resistance is an energy-absorbing element. Although the value of the resistance of a material does not vary with frequency, the effective resistance of a resistor or section of wire varies because of the skin effect, or the movement of the current to the outer edges of the conducting resistance. Another important characteristic of a resistance is the phase relation between the current through and the voltage across a resistor. The current is directly proportional to the applied voltage and there is no time lag between a change in voltage and a change in current.

Inductor. An inductor is a circuit element that has an impedance to the flow of current but absorbs no energy. When the voltage across an inductance is changed the inductance

Fig. 11. Layout of Headings

If it is necessary to use fourth-order headings, treat them like third-order headings but number them with Arabic numerals as we have in this sub section.

QUOTATIONS AND LISTINGS. Formal quotations are single-spaced, indented five spaces from the left margin and approximately the same number from the right. Quotation marks are unnecessary; single spacing and extra margin adequately identify the material as a quotation. If the quotation does not begin with the first word of a sentence in the original, the omission of words should be shown by a series of three periods (called "leaders"), and any deletion within the quotation should be similarly indicated. Triple-space above and below the quoted matter.

Informal, short quotations a sentence or less in length should be run in with the text. As Gaum, Graves, and Hoffman say, "Every quotation, therefore, must be so set off from the text that its nature is unmistakable."*

Formal listings, such as a numbered list of the parts of a device, are mentioned here because they are handled very much like formal quotations: indented an extra five spaces and single spaced. The list of rules below, under the next heading, illustrates the form.

EQUATIONS AND FORMULAS. If you find it necessary to present equations in the text of a report, the following "rules" should be observed:

1. Center each one on a separate line.

2. If more than one line in length, the equation should be broken at the end of a unit as before a plus or minus sign.

3. Place all of an equation on a single page if possible.

4. Allow ample space before and after the equation: three to four spaces above and below or even more if it is necessary to use symbols of more than letter height, $\int$, for example.

5. Use no punctuation after the equation.

6. Number equations consecutively in parentheses at the right margin.

7. If necessary, define symbols used.

Study the following illustration, adapted from a Civil Aeronautics Authority report:†

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* Carl G. Gaum, Harold F. Graves, and Lyne S. S. Hoffman, *Report Writing* (3d ed.; New York, 1950), p. 162.

† Pell Kangas, and George L. Pigman, *Development of Aircraft Windshields to Resist Impact with Birds in Flight*, Part II, Technical Development Report No. 74 (Indianapolis, Ind.: Civil Aeronautics Administration Technical Development, February, 1950), p. 13.

It is shown that the panel penetration velocity, where failure occurs in the butyral plastic interlayer, varies approximately as the logarithm of the plastic thickness. This can be expressed by the equation

$$T = Ke^{v/c} \tag{1}$$

where

T = thickness of vinyl plastic in inches,
v = penetration velocity of windshield panel in mph,
K and c = constants.

Informal Report Format

The terms "informal report" and "formal report" are vague, and are descriptive of a tendency rather than of an exact format. In general, form reports, letter reports, and reports designed for circulation only within an organization are called informal.

A typical informal report has no cover, no letter of transmittal, no title page, no table of contents, and no list of illustrations. If there is an abstract, it appears on page one, preceded by the title and the author's name and followed immediately by the text. The text is usually single-spaced. An example of an informal report will be found on page 246.

With the exceptions just noted, the suggestions for the format of a formal report apply equally well to an informal one. Discussion of form reports, one of the commonest varieties of informal reports, will be found in Chapter 15.

The format of a letter report, except that headings may be used in the text after the first paragraph, is simply the format of a business letter. The system of headings previously described is satisfactory. Besides the conventional block form letter, however, a modification of the military letter form is frequently used for informal reports. This form calls for "From," "To," and "Subject" caption lines and numbered sections or paragraphs. The military form is especially favored for interoffice or interdepartmental memoranda because, for one reason, the forms may be conveniently printed.

A Final Note: Relation of Format and Style

There is a problem as to whether a well-planned format can perform certain functions that are usually performed in the text. For example, does a table of contents in a report make it unnecessary to say anything about plan of development in the introduction? Does an abstract make it unnecessary to mention scope in the introduction? Does the use of a system of subheadings make transitions unnecessary?

The popularity of form reports clearly indicates that format can

take over certain textual functions, if we stretch the term "format" to include the detailed headings printed on a form report blank. In fact, the form report, which is an extreme case of the development of format, indicates both the potentialities and the limitations of the principle of assigning textual functions to format. An intelligently designed form report blank, when filled out by an intelligent man, is highly efficient. That is its strength. Its weaknesses are two. First, it can deal with only a limited number of situations. When something unusual happens, the report writer starts adding explanatory notes. The more initiative he has, and the more unusual the situations he encounters, the less useful the form report becomes. Second, the form report is impersonal. It gives the writer almost no opportunity to make himself felt as a human being. Perhaps it will help you to understand what we mean if you will try to imagine yourself attempting to present, in a form report, a persuasive statement of the advantages of a device you've just invented!

The point of these remarks is this: Yes, sometimes a table of contents makes a statement of plan in the introduction unnecessary, and sometimes a subhead is a sufficient transition; but the further you go toward letting the format take sole responsibility for such functions the closer you are getting to the form report, which is efficient within a limited range, but is neither particularly pleasing nor persuasive. In short, we urge that you recognize the many advantages of a clear and attractive format, but we also urge that you avoid letting it lull you into writing a careless text. Eight times out of ten, or thereabouts, you should write a transition even where there is a subhead; you should state the plan of development even when there is a table of contents; and you should clarify the scope even when there is an abstract. If you really want to be understood, try to communicate with every means at your command. To be even more specific about one question that often arises, we might add: Do not be concerned about duplication in the content of the letter of transmittal, the abstract, the table of contents, and the introduction. Such duplication is entirely acceptable, and is the common practice. See the comment in the example of partitioning at the end of Chapter 8.

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Graphic Aids

Introduction

In this chapter our general purpose is to provide an introduction to the extensive and important subject of graphic aids. More specifically, our purpose is to discuss some of the commoner varieties and functions of graphic aids and to consider elementary problems in their construction, exclusive of problems associated with their reproduction. Because the subject of graphic aids goes so far beyond what we have space for here, we strongly urge you to consult the pertinent volumes listed in the Appendix.

The graphic aids that are discussed in this chapter are charts, drawings and photographs, and tables. The term "chart" covers a broad field, however, which will actually occupy most of our attention.

Before entering into a discussion of the particular types mentioned, we must note two problems that arise in the selection and use of any graphic aid: (1) differentiating between dramatic emphasis and communication, and (2) establishing the proper relationship between the graphic aid and the text.

All graphic aids communicate facts to the reader, but some com-

municate with much more precision than others. This difference can easily be seen by comparing a curve carefully plotted on coordinate paper with the pictograph often found in newspapers. You might imagine, for example, that a newspaper has indicated the number of workers in a certain industry by a series of drawings of identical overalled men, each man representing 5000 workers except the last man, who is worth only 3000 and consequently lacks part of the left side of his anatomy. Such a pictograph may be dramatic but it is not precise. A curve plotted on coordinate paper, on the other hand, can be fairly precise in communicating information. For a technically trained reader, it may also be dramatic, but the dramatic element is obviously a secondary rather than a primary consideration. This difference between precise information and dramatization, qualified by reference to the intended reader, should always be noted in selecting a graphic aid.

Our second general problem is how to establish the proper relationship between the graphic aid and the text. Practically, this usually means deciding how much to say about the graphic aid, and deciding where to put it.

Our experience has been that writers often go to extremes in deciding how much to say. One writer will uselessly repeat in words practically everything that is shown in a graphic aid, and another will not even note that he has used one. If you question the second man, he will tell you that it's all there in the graph, why should he have to talk about it? You will have to make up your own mind as to which of these offenders is the worse. We suggest that you note your reactions on this point as you read various technical materials. You will probably find yourself most nearly satisfied when the following three practices are observed:

1. If a graphic aid has some bearing on a conclusion to be drawn, no matter how simple, a reference is made to it in the text. In contrast, an aid used solely for aesthetic or "dramatic" purposes may not be mentioned.

2. The significant points shown by an "informational" graphic aid are commented on in the text, but minor details are not mentioned.

3. Some directions are given on the reading and interpretation of a complex graphic aid. What "complex" means depends on the reader.

Finding the most effective location for a graphic aid is usually a simple matter. Informational aids that have a direct, immediate bearing upon conclusions or arguments presented in the text are usually

located as close as possible to the pertinent portions of the text. Informational aids of a more general, supporting character are put in an appendix, unless they are so few in number as to offer no serious interruption to the reading of the text. Aids used to dramatize are placed at appropriate points in the text. In general, graphic aids that belong in the text are likely to represent derived data; in the appendix, original data.

If the aid is small enough, it may be placed on a page on which text also appears. Usually it should then have a border. Larger aids should be put on a separate page. In a typed manuscript they may be bound on either the right or the left edge. If comments on the aid are pretty well concentrated on one page, the aid should be bound on the right edge in order that it may face the comment. If there are several pages to which the aid is pertinent, it may be wise to bind it on the left edge and locate it near the beginning of the comments (or place it in the appendix). A page occupied solely by a graphic aid is given a page number if it is bound on the left edge but is not given a page number if it is bound on the right edge.

In connection with the preceding discussion in general, you may find it helpful to study the use of the tables in the reports quoted at the end of Chapter 9, and the figures in the two reports quoted at the end of Chapter 6.

Charts

INTRODUCTION. Charts, or graphs, are a means of presenting numerical quantities visually so that trends of and relationships among the numerical quantities can be easily grasped. Although a chart does not, in most respects, permit as accurate or detailed a presentation of data as a table, it has the advantage of making a significant point more readily and in a manner that is more easily remembered. The basic kinds of charts are the line or curve chart, the bar or column chart, and the surface chart. Additional varieties are the circle or "pie" chart, the organization or line-of-flow chart, and the map chart. Each of these varieties will be discussed. First, however, we must review briefly some elements of chart construction. The elements to be discussed are the scales, the grid, the title, the scale captions, the source reference, and labels or a key.

Figure 12 illustrates the fundamental parts of a chart. Although it is a line chart, it could be easily converted into a bar or column chart by filling in a column from the base line up to the value for each division of the horizontal (abscissa) scale, and to a surface chart by shading the area beneath the line connecting the plotted points.

Most charts have only two scales, a horizontal (often called the abscissa) and a vertical (or ordinate). Typically, an independent variable is plotted on the horizontal scale, and a dependent variable on the vertical. Thus, if we were graphing the temperature rise of an electric motor, we would plot time on the horizontal scale and temperature on the vertical. It is desirable to have both scales begin at

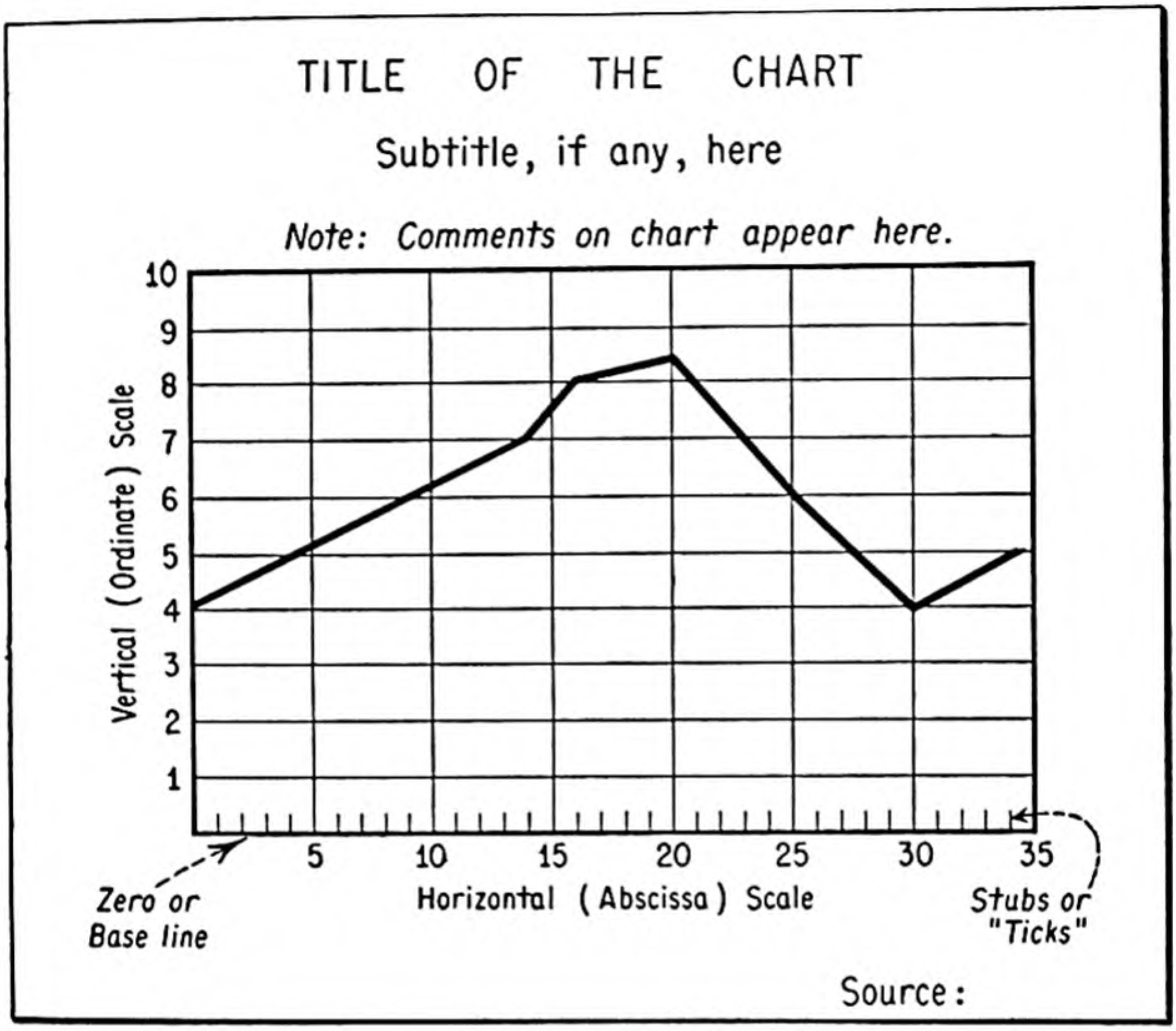


Fig. 12. Typical Chart Layout

zero, at their point of intersection, and to progress in easily read amounts, like 5, 10, 15, 20. Failure to observe either of these last two principles increases the possibility that the reader will misinterpret the chart. There are many cases, however, in which the scales cannot be started at zero. Suppose that values on the vertical scale, for instance, begin at a high numerical range, as in plotting temperature changes above 2000 degrees Fahrenheit. It would be impractical to begin the vertical scale at zero if intervals in the scale beyond 2000 are to be small. In such a case, it is occasionally desirable to give the

base line a zero designation and place a broken line between it and the 2000-degree line to indicate the gap in the numerical sequence of the scale (see Figure 17 for an approximate illustration).

Much of the effectiveness of a chart depends upon giving the proper slope or height to the line or bar or area plotted. The idea of movement and trend is emphasized by steepness and minimized by flatness. The American Standards Association suggests that an angle of slope over 30 or 40 degrees in a curve is likely to be interpreted as being of great significance, whereas an angle of 5 degrees would be regarded as of little significance. It is often difficult to satisfy all the ideal requirements: that is, the proper slope or height, an easily read scale, ample room for scale captions, and a little space between the highest point of the curve or bar and the top of the grid. (These last two points, not previously mentioned, are illustrated in Figure 12.) Sometimes it is desirable to use the long dimension of the coordinate paper for the horizontal scale to meet the above requirements. If this method still does not solve the problem, larger paper should be used, and a fold or folds made so that the folded chart, when bound into the text, will come somewhat short of the edges of the pages of the text. If you construct a grid yourself you should if possible use "root-two" dimensions (ratio of about 1:1.5) for the rectangle formed by the grid. Such dimensions are regarded as being aesthetically pleasing. (In a precise root-two rectangle, the long side is equal to the diagonal of a square made on the short side.) However, this advice must be qualified by observance of pleasing proportions between the shape of the grid and the shape of the page.

In general, you should use coordinate paper with as few grid lines per inch as the necessary accuracy in reading will permit. The purpose of the chart—the degree to which it is informational—and the probable error involved in your data determine the accuracy with which it should be readily possible to read the chart. Sometimes the use of stubs or "ticks," as shown in Figure 12, provides a good compromise between the precision afforded by numerous grid rulings and the clarity and force of fewer rulings. In a bar chart, the grid normally has only horizontal rulings if the bars are vertical, and vertical rulings if the bars are horizontal.

The title of a chart may be placed either at the top or the bottom. Usually, but not invariably, it is placed outside the rectangle enclosing the grid. If there is a figure number, it should appear either above or to the left of the title. In using 8½ by 11 coordinate paper you will often find it necessary, because of the narrow margins, to draw the axes an inch or so inside the margin of the grid to provide

space on the grid itself for the title, the scale numerals, the scale captions, and the source reference if there is one.

The scale captions need no particular comment, except that they should be easy to understand. Sometimes the whole effect of a graphic aid is spoiled by one ambiguous scale caption. See Figure 12 for illustration of the placement of captions. Don't forget to note units, like amperes or milliamperes, where they are necessary. The scale numerals or values are written horizontally if space permits.

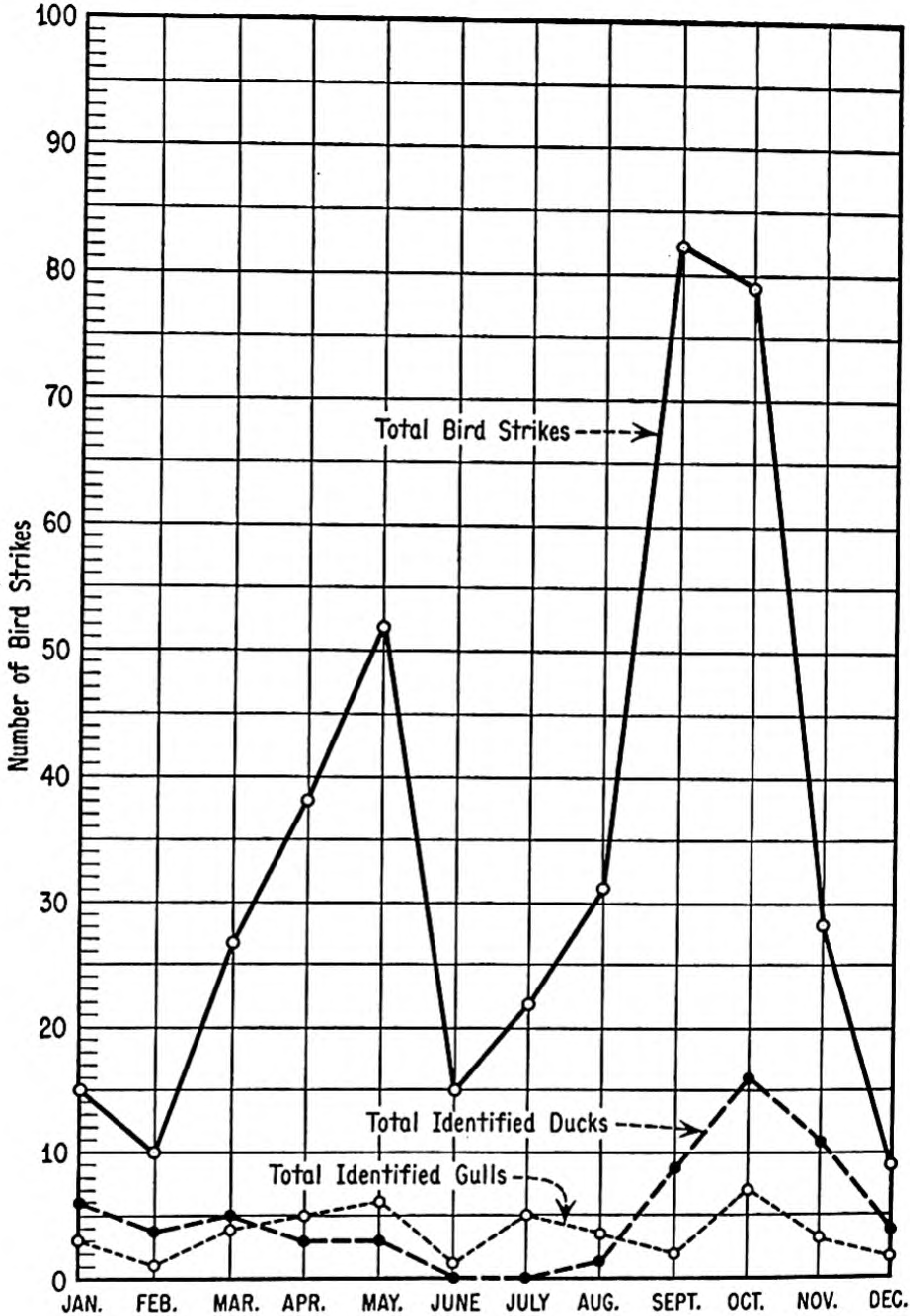
The principles governing the use and form of a source reference for a graphic aid are in general those that pertain to textual source references (see Chapter 22). More abbreviation is permissible in the reference to a graphic aid than in a footnote reference, however, because of the need to conserve space. Any abbreviation which will not confuse the reader is acceptable. The placement of the source reference is shown in Figure 12.

It is often necessary to use labels (Figure 14*), or a key to identify certain parts of a chart, such as bars or curves representing various factors or conditions. Labels often appear in a blank area with a "box" or border around them, but this is not always possible or necessary. If you are using commercially prepared coordinate paper, it may be helpful to put a box around the label even though there is no white space left for it. Labels for bars may be written at the end of the bar or, if there is no possibility of confusion, along the side (Figure 16). In circle or "pie" charts, the labels should be put within the individual segments. A "key" or "legend" is simply an identification of symbols used in a chart (see Figure 15). Another element occasionally found is a note, usually in a box on the grid, about some aspect of the chart.

We turn now to consideration of the types of charts.

Line Charts. Of all charts, the line chart (Figure 12) is the most commonly used. Simple to make and read, it is especially useful for plotting a considerable number of values for close reading or for plotting continuous data to show trend and movement. It is usually not as good as the bar chart for dramatic comparisons of amount. However, for making comparisons of continuous processes, the use of several curves on the same chart (Figure 13) makes the line chart superior to the bar chart. An illustration of this point might be seen in a chart in which the plate current of a triode tube is

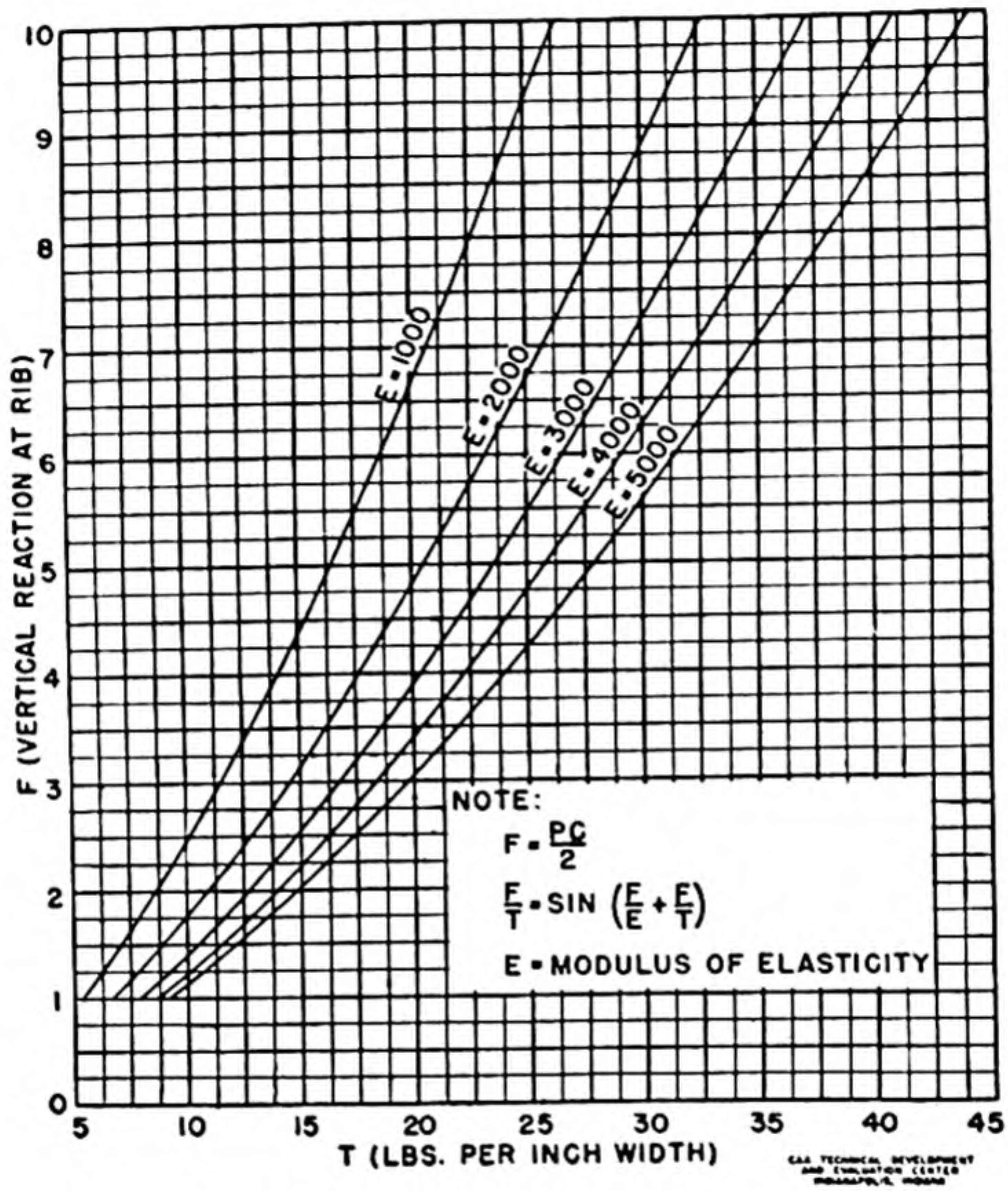
* The figure referred to here is the first of several in this chapter representing an investigation conducted by the Civil Aeronautics Administration, Technical Development and Evaluation Center, concerning the damage done to aircraft by collisions with birds in flight.



Total Monthly Number of Bird Collisions for Five-Year Period, 1942–1946, Involving Ducks, Gulls, and All Birds

Fig. 13. A Multiple-Line Chart. Source: *CCA Technical Development Report No. 62, Fig. 4.*

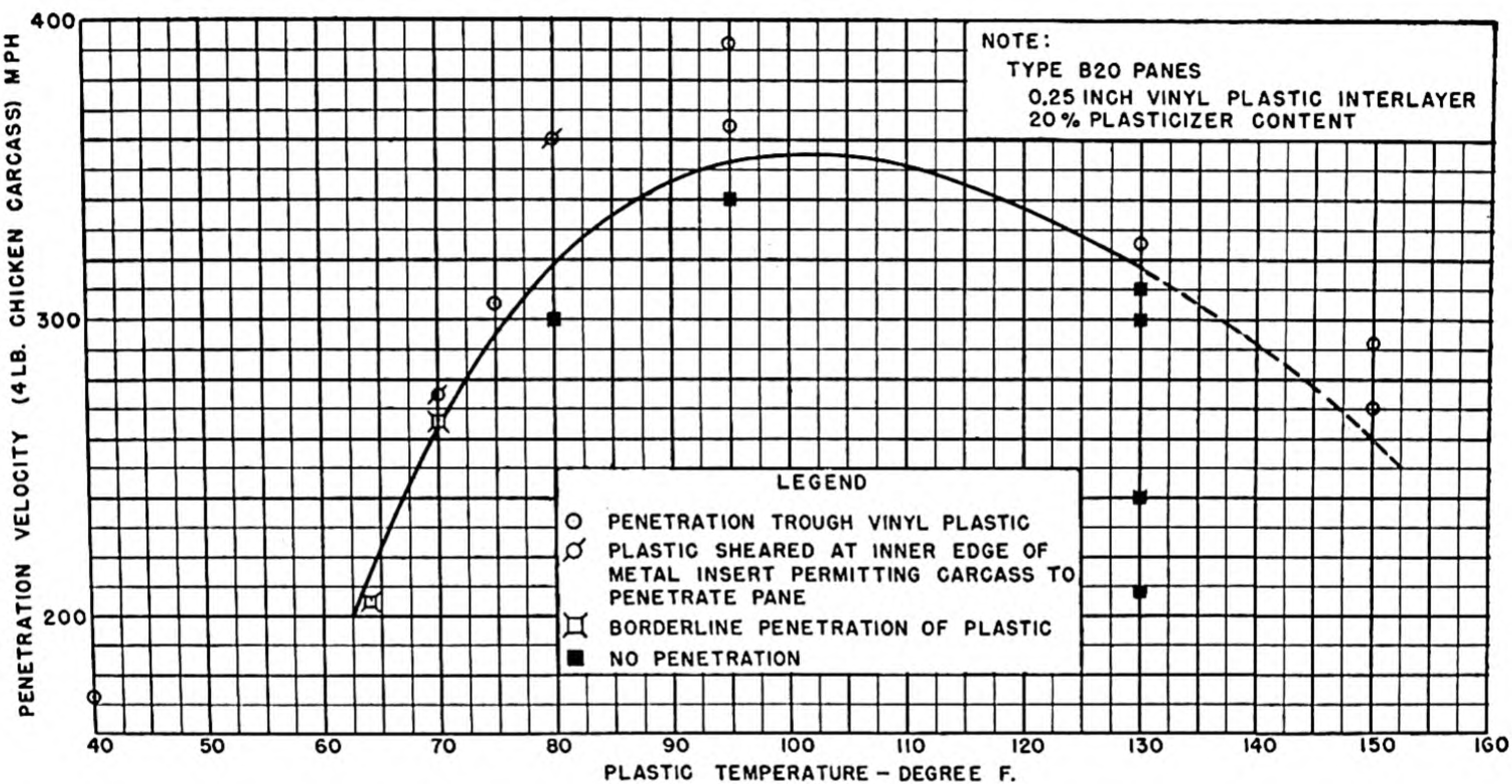
plotted on the vertical scale against the grid voltage on the horizontal. For different values of plate *voltage*, the relationship between the plate current and grid voltage is different; therefore, if one curve is drawn for each of several different values of plate voltage, the result of such changes is very effectively shown.



Graph for Solving Tension Equation

Fig. 14. Multiple-Line Chart with Accompanying Key. Source: *CAA Technical Development Report No. 129, Fig. 2.*

In a multiple-line chart of the kind just mentioned, labels are often written along the sides of the lines, without boxes. When lines intersect, the lines may be broken in various ways (dotted and dashed) to help in differentiating them; or colors or symbols with an accompanying key may be used (Figure 14). Particularly when lines inter-



The Effect of Plastic Temperature on Penetration Velocity of Type B20 Pane

Fig. 15. A Single-Line Chart with a Faired Curve. Source: *CAA Technical Development Report No. 105, Fig 11.*

sect, you should be careful not to put too many lines on a chart, nor too many within a small area of the chart. The latter problem can of course be alleviated somewhat by the use of an appropriate scale on a large sheet of paper. If comparisons are to be made between different charts, the scales used on the charts should be identical.

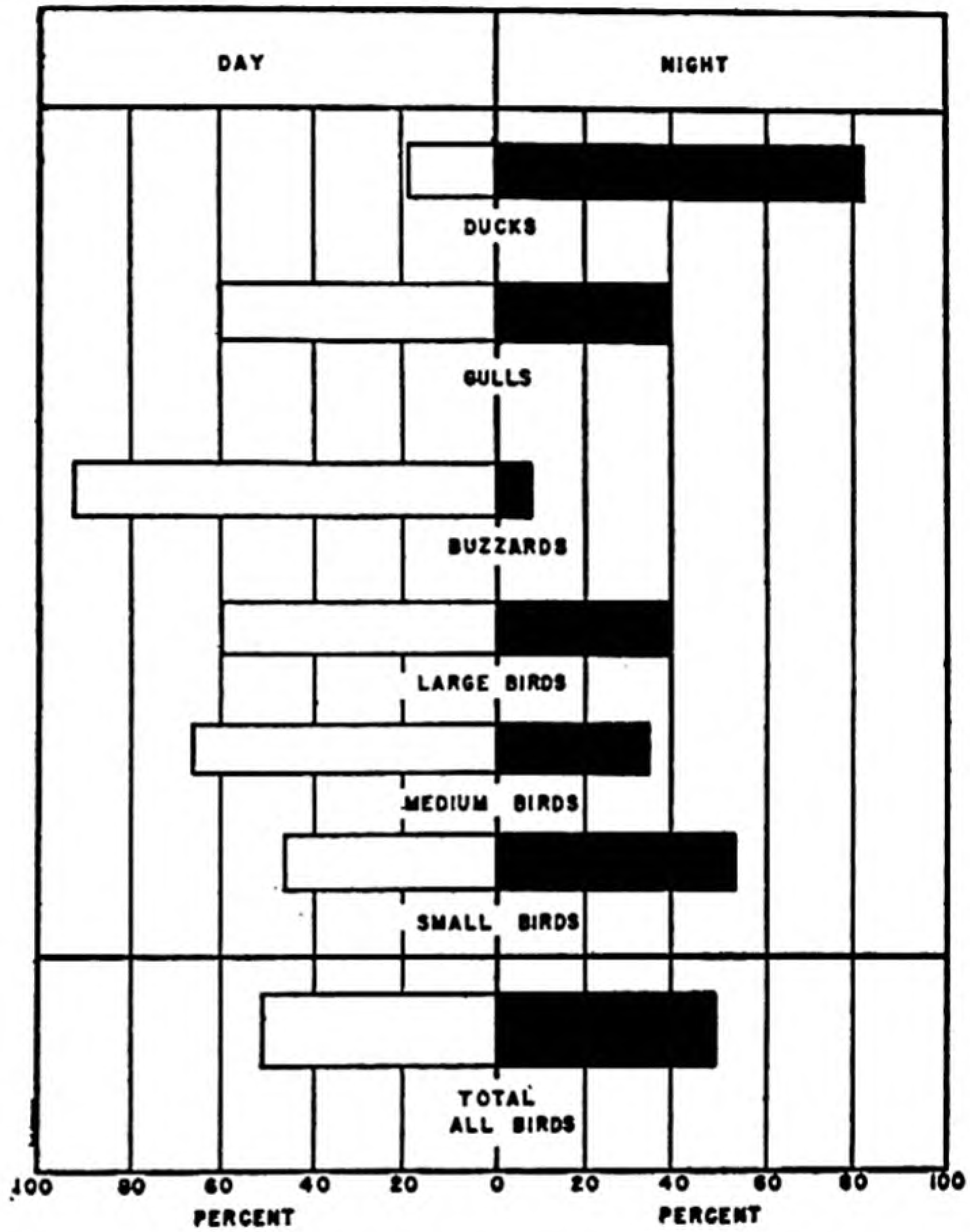
Another problem in either single- or multiple-line charts is whether the line connecting points plotted should be drawn straight from point to point or smoothed out (faired) (see Figure 15). If you are showing the trend of a continuous process, like the temperature rise of a motor, it is usually desirable to make a faired curve; but if the process or change is not continuous, fairing the curve may be misleading. For example, if you were plotting an increase in student enrollment in a certain university for successive years, and your data showed enrollments of 10,000, 10,200, 14,000, and 14,300, a fairing of the curve would obscure a significant fact, the sharp increase in the third year, and would also falsely imply that the enrollment was rising steadily throughout each year. Incidentally, where precision is necessary a point should be plotted by making a very small dot and then circling it lightly with a pencil so that it can later be found easily.

The foregoing discussion has been concerned only with the simplest and commonest of line charts. There are a great many possible variations of elements, including the use of special grids like the logarithmic and semilogarithmic, that it is important to know about. Again we urge you to consult the books listed in Appendix A.

Bar Charts. Bar or column charts represent values or amounts by bars of scaled lengths. They are useful for showing sizes or amounts at different times, the relative size or amount of several things at the same time, and the relative size or amount of the parts of a whole. The bar chart is in general preferable to the line chart for making dramatic comparisons, provided the items compared are limited in number. Arranged vertically (these are often called "column" charts), the bars are effective for representing the amount of a dependent variable at different periods of time; arranged horizontally, the bars are effective for representing different amounts of several items at one time. See Figures 16 and 17. Note the difficulty about scale in Figure 17.

Although the bars of a bar chart may be joined, it is more common practice to separate them so as to improve appearance and increase readability. The bars should be of the same width, and the spacing between them should be equal. The proper spacing depends upon keeping the bars close enough together to make comparison easy, yet far enough apart to prevent confusion. Another convention of bar

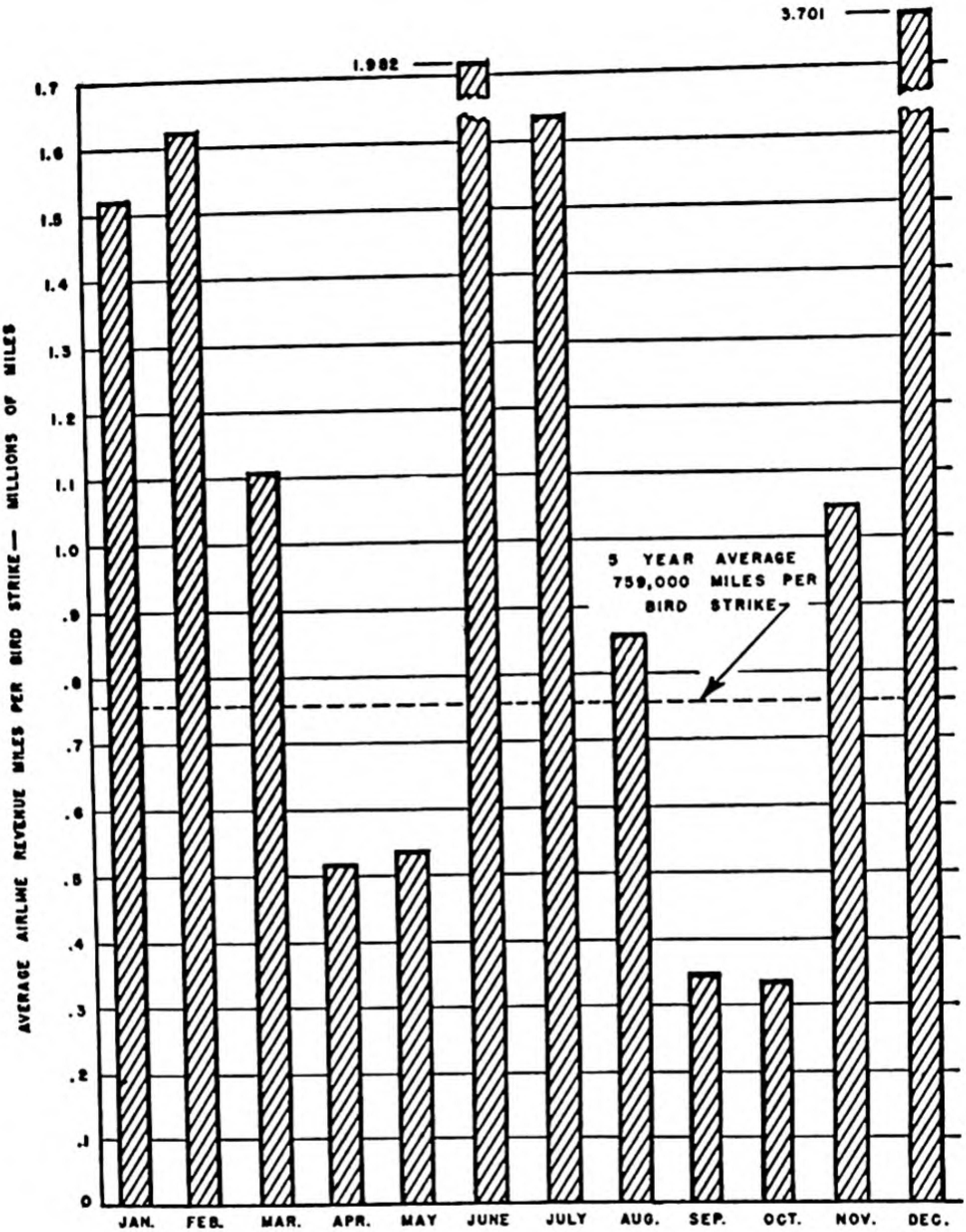
chart construction is that the bars are arranged in order of increasing or decreasing length. This convention applies to charts in which each bar represents a component; it does not apply of course to those representing a time series.



Distribution of Strikes Involving Identified Bird Types According to Occurrence during Daylight or Darkness

Fig. 16. A Horizontal Bar Chart. Source: *CAA Technical Development Report No. 62, Fig. 11.*

Portions or subdivisions of an individual bar may be used to represent components or percentages. A single bar so subdivided is usually called a 100 per cent bar chart. Shading and hatching are employed to differentiate the portions, and labels are used, or a key. Darker shadings (often solid black) are used to the left of horizontally



Average Monthly Bird Strike Frequency for Five Years, 1942–1946, Compiled from Reports Submitted by Airline "A"

Fig. 17. A Bar Chart. Source: *CAA Technical Development Report No. 62, Fig. 1.*

placed bars, with lighter shadings or hatchings being used for successive divisions to the right; on vertically arranged bars, the darker shadings are used at the bottom. Colors may be used instead of shadings and hatchings.

One of the more interesting developments in bar chart making is the pictograph, mentioned earlier in this chapter. The pictograph substitutes symbolic units, like the figure of a man or the silhouette of a ship, for the solid bar. The purpose of the pictograph is to increase interest and dramatic impact. The difficulties of preparing this kind of chart make it impractical for most technical reports, but when a report is to be distributed to a large audience of laymen, and when professional help is available for preparing the illustrations, the pictograph may prove highly desirable.

Surface and Strata Charts. A single-surface chart is constructed just like a line chart except that the area between the curve line and the base or zero line is shaded. Multiple-surface or strata

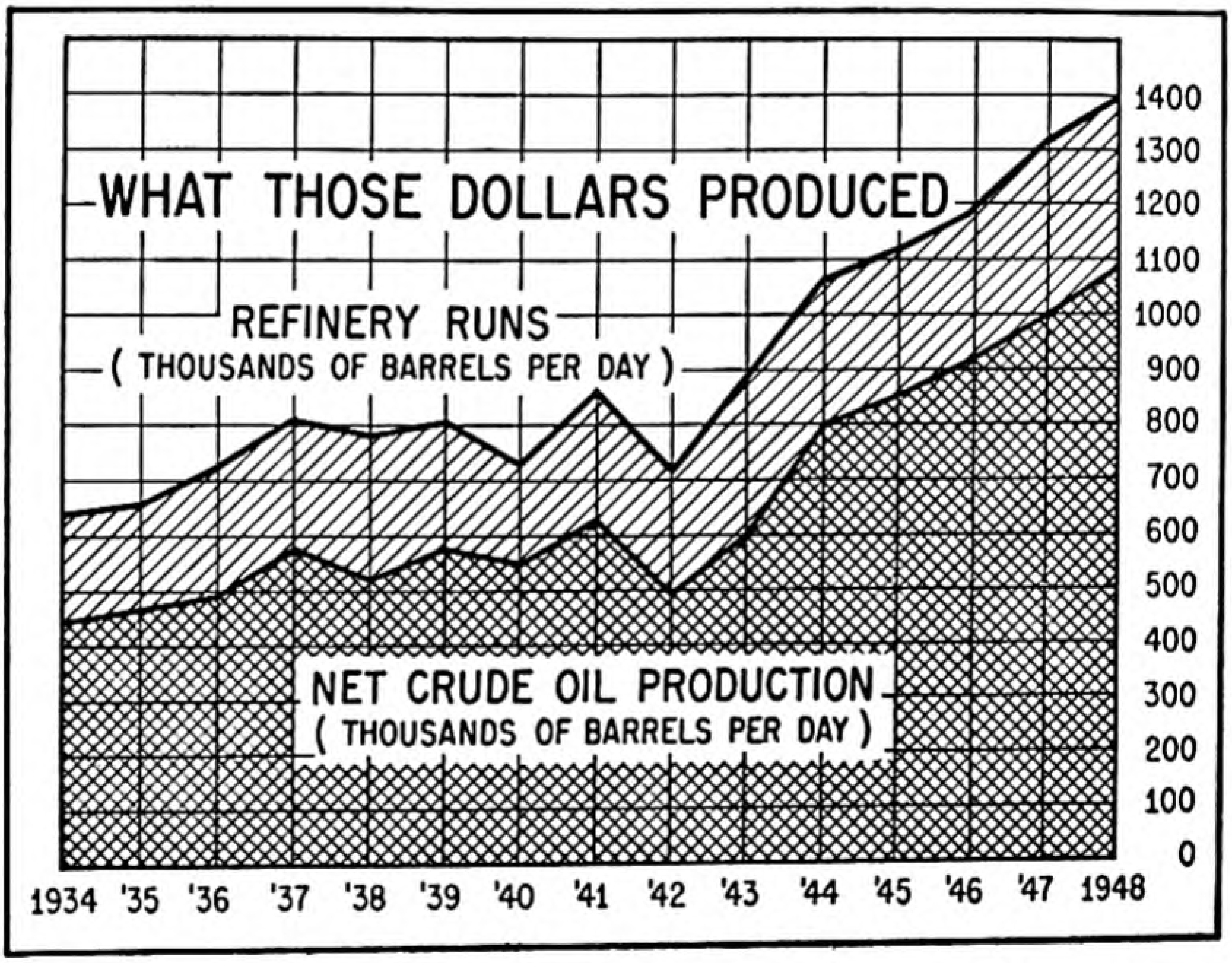


Fig. 18. A Surface Chart. Reprinted from The Lamp, 31 *(November, 1949), 5. This is a publication of the Standard Oil Company (N.J.).*

charts (sometimes called band or belt charts) are like multiple-line charts with the underneath areas shaded in differentiating patterns, i.e., the vertical widths of shaded or hatched surfaces, strata, or bands communicate an impression of amount. They can be satisfactorily

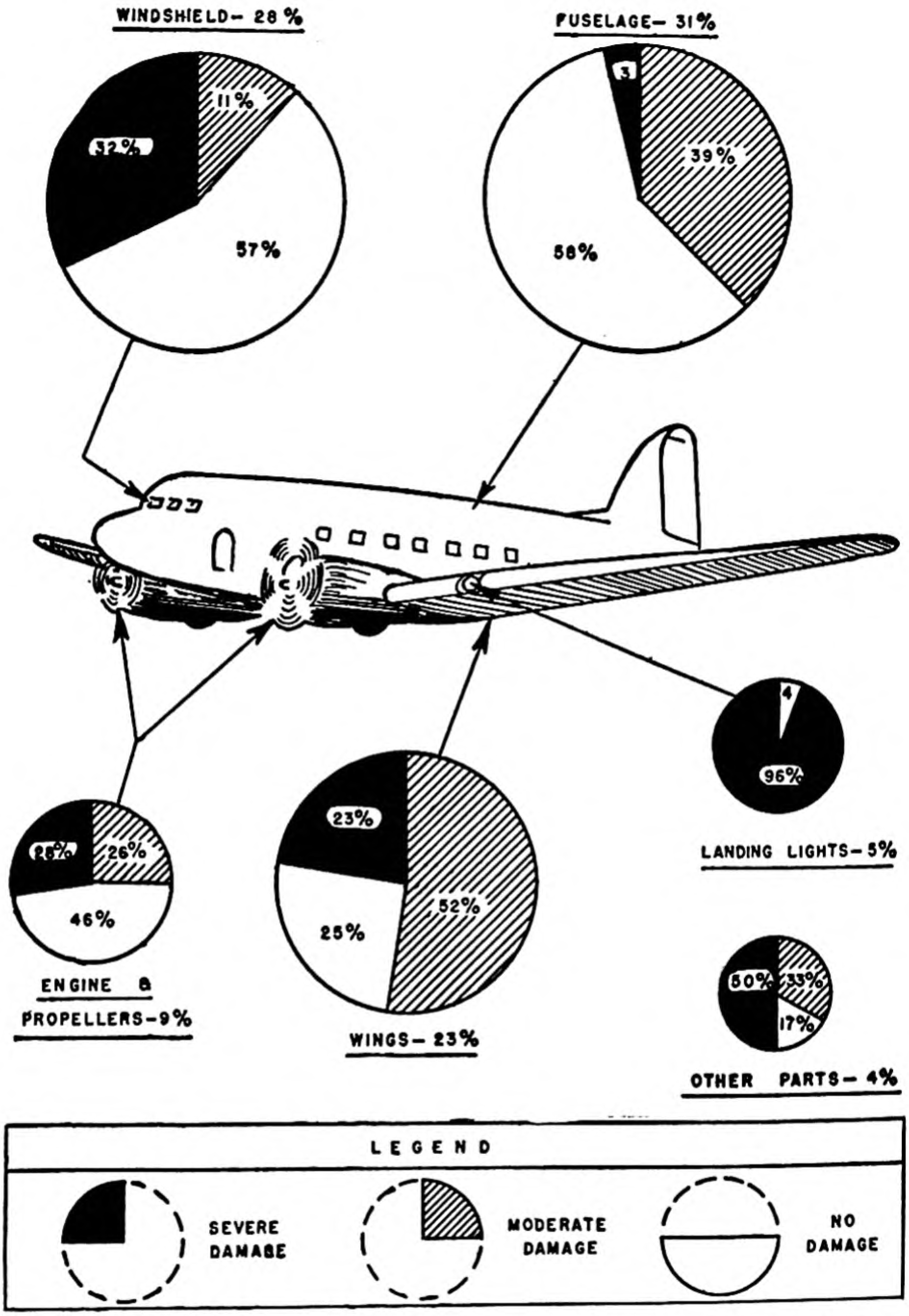
used to achieve greater emphasis than is possible with a line chart of the same data when amount is more important than ratio or change. They are not intended for exact reading, and should never be used when the layers or strata are highly irregular or where the different lines plotted intersect. Gradual, regular movement or change can best be charted by this means (see Figure 18). As in the subdivided bar chart, darker shadings should be used at the bottom.

CIRCLE OR "PIE" CHARTS. A circle or pie chart is simply a circle of convenient size, the circumference of which represents 100 per cent, and the segments or slices of which are drawn to show percentage distribution of the whole. Since it is difficult to estimate the relative size of segments, labels and percentages must be placed on each segment. Not a particularly effective graphic aid, the circle chart may be used for dramatic emphasis and interest so long as the subdivisions are not numerous. Figure 19 illustrates an interesting application. One point to remember in case you use a circle chart is that the segments are measured clockwise from a zero point at the top of the circle. Labels should be placed horizontally, not radially from the center.

Occasionally you may see circles, squares, cubes, or spheres of different sizes used to compare amounts. The difficulty of comparing relative sizes, especially of cubes or spheres, makes these devices of no real use. We recommend that they be avoided. The line, bar, or surface chart will do better.

FLOWSHEETS AND ORGANIZATION CHARTS. A flowsheet is a chart which makes use of symbolic or geometric figures and connecting lines to represent the steps and chronology of a process. An organization chart is like a flowsheet except that instead of representing a physical process it represents administrative relationships in an organization.

The flowsheet (Figure 20) is an excellent device for exhibiting the steps or stages of a process, but its purpose is defeated if the reader finds it difficult to follow the connecting lines. Flowsheets should generally be planned to read from left to right, and the connecting lines should be arrow-tipped to indicate the direction of flow. The units themselves, representing the steps or stages, may be in the form of geometric figures or symbols. The latter are simple schematic representations of a device, such as a compressor, a cooling tower, or a solenoid valve. Standards for such symbols have been adopted in a number of engineering fields today, and you should make it a point to familiarize yourself with the symbols acceptable in your field. Publications concerning symbols may be obtained from the



Location, Severity, and Relative Frequency of Bird Strikes on Airplanes

Fig. 19. Circle or "Pie" Diagrams. Source: *CAA Technical Development Report No. 62, Fig. 7.*

MODERN KELLOGG 4000 BBL. FLUID CATALYTIC-CRACKING UNIT

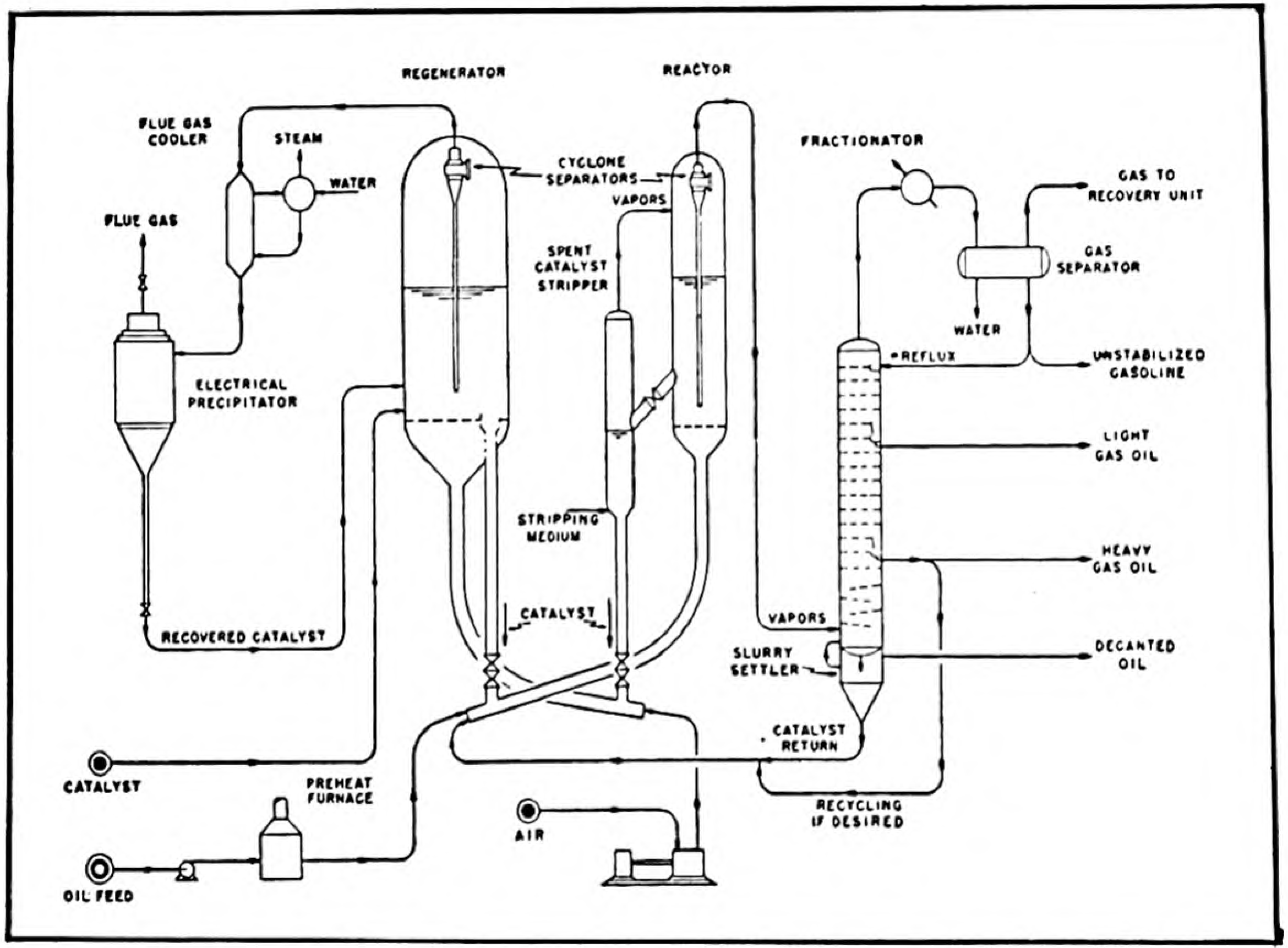


Fig. 20. A Chemical Process Flowsheet. Source: *The Kelloggram, 1946 Series, No. 2.*

American Standards Association. These symbols may be used, by the way, in drawings as well as in flowsheets. Labels should always be put on geometric figures. Whether labels should be used with symbols depends on the intended reader.

Since a generous amount of white space is essential to easy reading of a flowsheet and since the flowsheet reads from left to right, the display will often need to be placed lengthwise on the sheet. This makes it necessary for the reader to turn the report sideways to read the chart, but this is better than crowding the figures into too narrow a space. If space requires it, a sheet of larger than page size may be used and folded in.

Flowsheets, like other figures, should usually be enclosed in a ruled border, and the title and figure number centered at the bottom, inside the border.

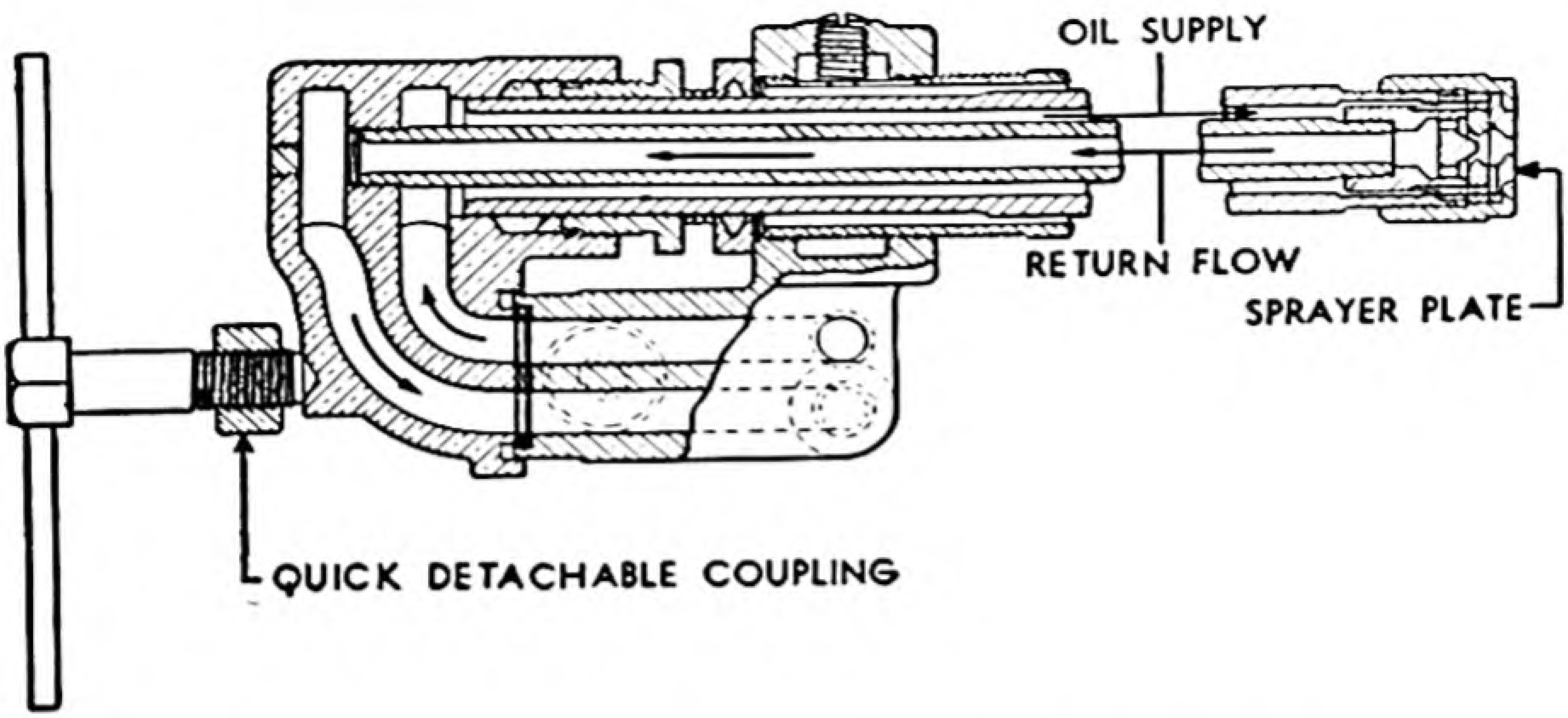
Organization charts are very similar to flowsheets. Rectangular figures represent the component units of an organization; connecting lines, as well as relative position on the sheet, indicate the relationship of units. Good layout requires that the figures be sufficiently large so that a lettered or typed label can be plainly and legibly set down inside them, and they must be sufficiently far apart so that the page will not appear crowded. Organization charts usually read from the top down.

Colored flowsheets and organization charts are very effective for popular presentation. Like the pictograph, such color charts require the services of trained artists and draftsmen.

MAP CHARTS. The map chart is useful in depicting geographic or spatial distribution. It is made by recording suitable unit symbols on a conventional or simplified map or differentiated area of any sort (like electron distribution in a space charge). It is particularly important in a map chart that the symbols and lettering be clear and easy to read. Geographic maps suitable for use in making map charts are readily available from commercial suppliers.

Drawings, Diagrams, and Photographs

Drawings and diagrams are especially valuable for showing principles and relationships that might be obscured in a photograph, but of course they are sometimes used instead of photographs simply because they are usually easier and less expensive to prepare. A photograph, on the other hand, can supply far more concreteness and realism than drawings or diagrams (see Figure 21). We are using the terms "drawing" and "diagram" loosely to refer to anything from a simple



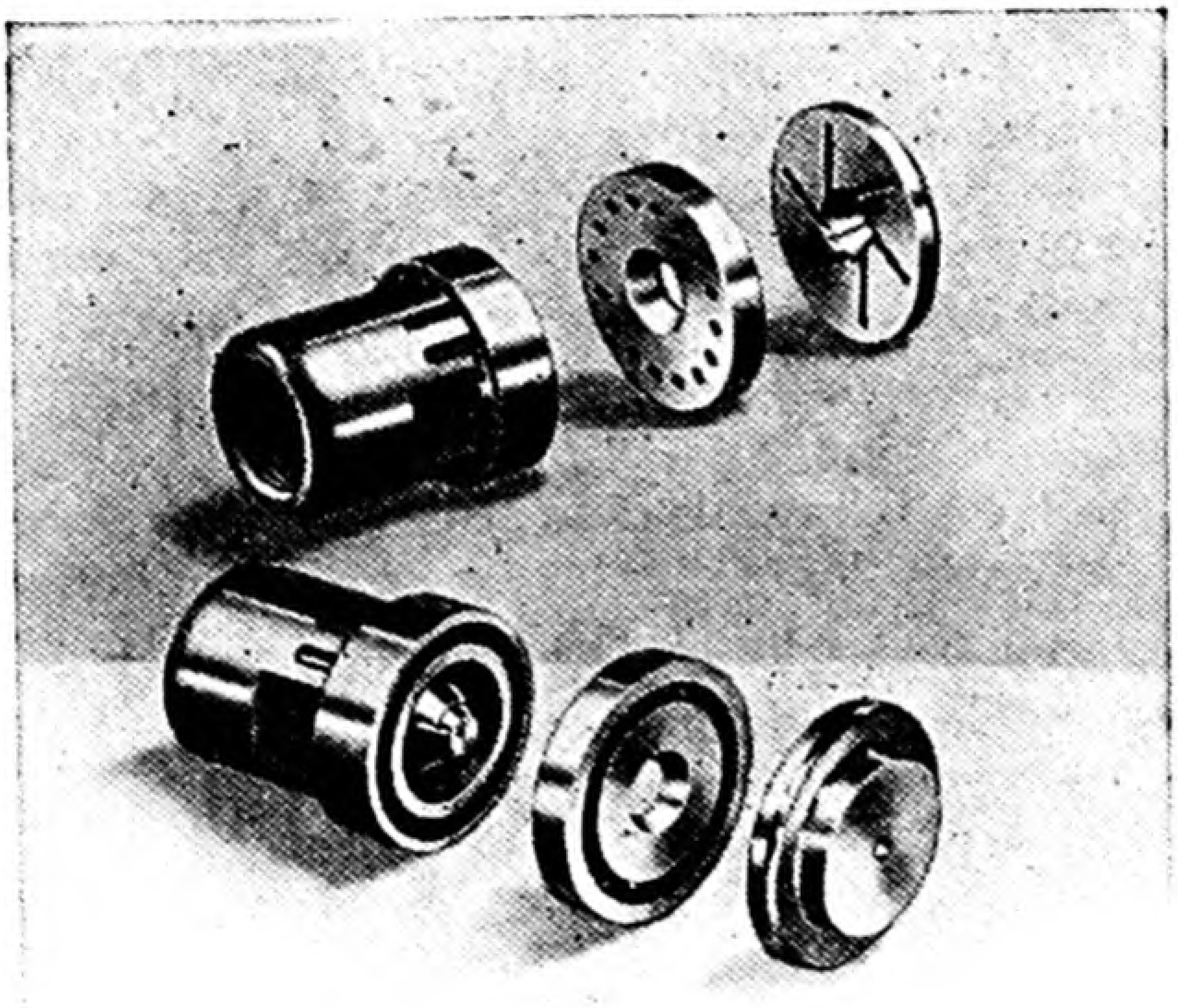


Fig. 21. A Drawing and Photograph of Wide-Range Return-Flow Atomizer.
Source: *Babcock & Wilcox Bulletin G–68 (1950).*

electronic circuit diagram to an elaborate structural blueprint or a pictorial representation of a complex mechanical device.

Parts of drawings should be plainly labeled so as to make textual reference clear and meaningful. If the drawing is of a simple device with but few parts, the names of the parts may be spelled out on the drawing itself, with designating arrows; if the drawing is of a complex device, with a large number of parts, letter symbols or numbers with an accompanying key should be used. Figure number and title

should be centered at the bottom, inside the border if one is used. If a source reference is necessary it should appear in the lower right-hand corner.

Photographs should be taken or chosen with special attention to how prominently the elements important to your discussion stand out. Very often this principle necessitates the use of an artificial background. A cluttered background distracts attention, not infrequently producing the impression that the photograph was originally intended as a puzzle, with a prize for anybody who could find gear B.

Glossy prints are better than flat prints because of their greater effectiveness in reproducing high lights and shadings. Each print should have an attractive margin of white space. If smaller than page size, prints may be satisfactorily mounted by use of rubber cement. Rubber cement has less tendency than paste or glue to wrinkle the page.

The figure number and title, as well as explanatory data, should be put directly on full-page photographs in black or white ink.

Tables

The table is a convenient method of presenting a large body of precise quantitative data in an easily understood form. Tables are read from the top down in the first column and to the right. The first, or left, column normally lists the independent variable (time, item number, and so on) and the columns to the right list dependent variables (see Figure 22). The table should be designed so as to be self-explanatory, but textual comments on it should be made according to the same principles that apply to the use of a chart.

In order to make a table easy to read, you should leave ample white space in and about it. If the table appears on a page on which there is also typed text, triple-space above and below the table. Leave a generous amount of space between columns and between the items in a column. The title and the table number should appear at the top. It is advisable to use Arabic numerals for the table number if Roman numerals have been used in the same report for numbering other kinds of graphic aids, or vice versa.

In separating parts of the table from one another—that is, one column from another, or one horizontal section from another—use single lines in most instances; but where you wish to give special emphasis to a division use a double line. Some people make it a practice always to use a double line across the top of the table, under the title. Usually a single line should be drawn across the bottom of the

table. The sides may be boxed or left open, as seems most pleasing. But we will add this: in case of doubt as to whether a ruling should be used at any given point in the table, leave it out. More harm will probably be done by too many lines than by too few, provided ample white space has been left.

TABLE II

CENTRIFUGAL FORCE CALIBRATION DATA

Element No.	Maximum g	Minimum g	Average g	Spread in g
1	2.21	1.65	1.93	0.56
	2.20	1.65	1.93	0.50
2	2.48	2.25	2.36	0.23
	2.50	2.22	2.36	0.28
3	3.08	2.59	2.84	0.49
	3.12	2.58	2.85	0.54
4	3.07	2.60	2.84	0.47
	3.10	2.60	2.85	0.50
			Average Spread	0.45

Fig. 22. Illustration of Table Layout. Source: *CAA Technical Development Report No. 48.*

Align columns of numerals on the decimal point, unless units of different quantities (like 2000, representing lb and 0.14 representing per cent) appear in the same column, in which case the column should be aligned on the right margin.

A heading should be written for each column, with the initial letter of important words capitalized. The headings should be written horizontally if possible, but if that would use too much space they may be written vertically. Indicate units (like volts, Btu, cu ft) in the heading so that the units will not have to be noted in the column. If you have data in different systems of units, you should convert all to the same system before entering them in the table.

If the data in the table are not original, acknowledge their source in a footnote just below the bottom horizontal line of the table. Instead of using a superscript number in the table to refer to the footnote, use a letter symbol (roman), an asterisk, or some other convenient symbol. Tabular footnotes, that is, notes that refer to specific items in the table itself, should be placed between the bottom line of the table and the source note, if one is needed. Tabular

footnotes may be keyed with the asterisk or a roman superscript letter, whichever is not being used with the source note.

Conclusion

Graphic aids in their simpler forms are easy to prepare and easy to understand, and in either their simple or more complex forms they often serve to convey information or provide dramatic emphasis with an effectiveness that would be difficult or impossible to achieve in writing. On the other hand, if they are relied on too much they may become a hindrance rather than a help. You should regard this chapter as merely a short introduction to the uses and techniques of one of the more valuable tools of science and technology.

section six

The Library Research Report

The preparation of a library research report has two distinct advantages for a student of technical writing. In the first place, it is usually only through the use of library materials that sufficient subject matter is available for a report of several thousand words; and the writing of a report of this length is a valuable experience. Nobody can learn to write without writing. In the second place, the use of the library for such a purpose is itself an opportunity. The next best thing to knowledge is, for the professional man, knowing where to acquire knowledge. That means, in effect, knowing how to use a library.

The two chapters in this section are devoted to a discussion of how to use the library and of how to write a library research report.

21

Finding Published Information

Introduction

The ability to find with a minimum of time and effort what has been published on a subject is an essential skill for the student and the professional man. Students must frequently use the library in order to supplement information in their texts. Professional men use library resources to keep abreast of developments in their field and to get data for the solution of special problems. Almost all industrial concerns and laboratories nowadays maintain technical libraries for the use of their personnel.

The primary object of this chapter is to introduce you to various sources of information about what has been published on a given subject. There are many more sources than could be presented in this chapter, but you will find that once you have begun to make a deliberate study of library resources one thing will lead to another and your ability to locate books and articles will steadily increase. The materials described in this chapter should be sufficient to provide for your needs in the preparation of the library research report which is discussed in the next chapter.

Guides to the location of books will be considered first, then guides to the location of periodical articles, followed by a variety of other aids.

Books

The most obvious source of information about books is the library card catalogue. In addition, there are special works of various sorts that should be noted.

THE LIBRARY CARD CATALOGUE. The card catalogue is an index to the books a library contains. It is a file, on 3 by 5 cards, of every book in the library. Some libraries have at least three cards for every book: an author card, a title card, and a subject card. In many libraries there are several subject cards for certain books, the exact number depending upon how many distinct subjects are treated in the book. In other libraries there may be no subject cards at all, only author and title cards, and sometimes only author cards.

It is important to remember that there may be several subject headings under which the book might be listed. For instance, if you are interested in the subject of beta rays you would naturally look for "Beta" in the alphabetical file. If you were to find nothing under that heading, other possibilities would be "Rays," "Electrons," and "Radioactivity." Cross reference cards will often be included in the files to guide you to other headings in case book cards are not filed where you first look. Identical cards may appear in several places, of course.

A good deal can be learned about a book and its potential usefulness in a research project by careful examination of the card entry itself. Let's take a look at a typical card and see what information it contains and how that information may help you decide whether the book could be of use.

1. The call number recorded on the upper left-hand corner of the index card is the book's classification (in this case according to the Dewey decimal system), which enables a library attendant to find the book. You do not need to be concerned with the details of this system of book classification, but you do need to take pains to copy the call number accurately on a call slip when you request a book.

2. The author line gives the full name of the author of the book plus the date of his birth and, if he is deceased, that of his death.

3. Title and publishing data are given next. This entry includes the full title of the book (and subtitle, if there is one), the author's name, the place and date of publication, and the publisher. All of this information, with the exception of subtitle, is needed for a bib-

liographical entry. It is also useful in determining the possible value of a book. You will need, especially, to note the date of publication to learn whether the book's treatment of the subject is up to date. Experienced researchers tend also to attach some significance to the name of the publisher on the theory that well-established publishers of good reputation are more likely to publish books of merit than little-known publishers.

1 621.75
R62f

2 **Roe, Joseph Wickham, 1871–**

3 Factory equipment, by Joseph W. Roe ... and Charles W. Lytle ... 1st ed. Scranton, Pa., International textbook company, 1935.

4 vii, 517 p. illus., diagrs. 21½cm. (*Half-title:* International texts in mechanical engineering, O. F. Taylor ... consulting editor)

5 "References" at end of each chapter.

6 1. Machine-shops. 2. Machine-tools. 3. Factory management. I. Lytle, Charles Walter, 1890– joint author. II. Title.

35—26733

7 Library of Congress TJ1125.R6

——— Copy 2.

Copyright A 87927 [36f5] 621.75

Fig. 23. A Library Index Card

4. The next entry, called the "collation," gives information about paging, illustrations, the size of the book (in centimeters), plus information, if pertinent, about the series the book appears in. The investigator of a technical subject may be particularly interested in whether a book contains illustrations. When a book does contain illustrations, a note like this may appear: "front., illus., plates, diagrs." If a book contains an introduction, its length will be given in lowercase Roman numerals.

5. Notes as to bibliographies, contents, and the like may appear next. The researcher will be especially interested in notes about content, for from them he can often determine whether it will be worth while to check out the book. A notation about bibliography may suggest that he can find leads to other sources.

6. At this point "tracings" are given, or subject headings under which the book is also indexed. These too are sometimes useful in

giving an idea of the subject matter coverage of the book and in locating other books.

7. Classification data appear at this point. Of little or no interest to the student researcher, they give the Library of Congress call number, the date of card code number, the order code number for this card, and so forth.

Altogether, then, quite a lot of information about a book is recorded on an index card, enough so that it is worth while to read it carefully in an effort to determine without checking out the book whether it will be of use.

OTHER GUIDES TO BOOKS. There are several sources of information about books besides the card catalogue that deserve mention. *The Technical Book Review Index* gives a brief account of the critical reception of new technical books. *Guide to Technical Literature* (1939), by A. D. Roberts, provides bibliographies in nearly all branches of engineering and technology, but it is of no value for publications after 1938. *The United States Catalog of Books* (1900—) is an index of books published in this country. It is supplemented by the *Cumulative Book Index*, which is issued monthly, quarterly, semiannually, and annually. Mudge's *Guide to Reference Books* (1936; supplements in 1939 and 1941) is another valuable source of information.

Periodicals

It is seldom that a research project can be completed without the use of articles appearing in professional journals and other periodicals, particularly because it is in these publications that the most recent information is found. There are numerous periodical indexes, but three that are of especial interest are the *Engineering Index*, the *Industrial Arts Index*, and the *Readers' Guide to Periodical Literature.*

1. *Engineering Index.* An annual author-subject alphabetical listing of articles appearing in professional periodicals in all engineering fields is found in the *Engineering Index.* The articles appearing in some of the magazines indexed may be a bit too advanced for some undergraduate researchers, but this is a reference every engineer should become acquainted with. In addition to bibliographical data, it gives some information about the content of listings.

2. *Industrial Arts Index.* A particularly useful guide to articles in technical and semitechnical journals is the *Industrial Arts Index.* About two hundred and fifty magazines, covering the fields of business, finance, science, and technology, are indexed. With general subject headings broken down into subdivision classifications, this in-

INDUSTRIAL ARTS INDEX

DEEP ROCK oil corporation
Wider profit margin seen. Barron's 30:17-18 D 18 '50

DEFENSE housing. See Housing—United States—Defense workers

DEFENSE manpower, Office of. See United States—Defense manpower, Office of

DEFENSE power administration
McManus, Georgia Power head, to take over as administrator. Elec World 135:40 Ja 1 '51

DEFENSE production act
Defense production act of 1950; terms and early action. Mo Labor R 71:453-7 O '50
You and government controls; synopsis of regulations and revisions under the Defense production act of 1950. Iron Age 167:365-70 Ja 4 '51

DEFENSE production administration
DPA established to stimulate defense output; Harrison head. Oil Paint & Drug Rep 159:5 Ja 8 '51
Harrison heads DPA as straw boss to Wilson. Iron Age 167:80 Ja 11 '51
U.S. control agency shuffle forecasts early restrictions. Eng N 146:23 Ja 11 '51

DEFENSE transportation administration
D.T.A. to be kept on sensible plan. J. K. Knudson. Ry Age 129:39+ D 30 '50

DEGRADATION
Degradation of alkenyltrimethylammonium hydroxide. C. D. Hurd and E. H. Ensor. bibliog Am Chem Soc J 72:5135-7 N '50

DEHYDRATION
Dehydration of phenylmethylcarbinol with iodine. A. J. Castro. bibliog Am Chem Soc J 72:5311-12 N '50
3, 6-Dihydro-2, 4, 6-trimethyl-2H-pyran, a product of the dehydration of 2-methyl-2, 4-pentanediol. S. A. Ballard, R. T. Holm and P. H. Williams. bibliog Am Chem Soc J 72:5734-8 D '50
Equilibrium and thermodynamic relation in the vapour-phase catalytic dehydration of ethyl alcohol to ethyl ether. F. H. H. Valentin. Chem Soc J p498-500 F '50

DEHYDROCHLORINATION. See Hydrochloric acid

DEHYDROPERILLIC acid
Methyl ester of dehydroperillic acid, an odoriferous constituent of western red cedar (thuja plicata). E. F. Kurth. Am Chem Soc J 72:5778-9 D '50

° ° °

DEPRECIATION
Accelerated depreciation of emergency plant facilities. Mill & Factory 47:112 D '50

DESIZING (textiles)
Desizing and sizing; abstract. I. Teplitz. Am Dyestuff Rep 39:787 N 13 '50

DESOXYHYDROXY corticosterone
Sterols; 17 a-hydroxy-11-desoxycorticosterone (Reichstein's substance S). P. L. Julian and others. bibliog Am Chem Soc J 72:5145-7 N '50

DESOXYPENTOSE
Deoxy-sugars; further observations on the Dische reaction for 2-deoxypentoses. W. G. Overend, F. Shafizadeh and M. Stacey. Chem Soc J p 1027-9 Ap '50

DEUTERONS
Angular distribution of the $Al^{27}(d,a)Mg^{25}$ reaction and energy levels in Mg^{25}. A. D. Schelberg and others. bibliog diags Phys R 80:574-9 N 15 '50
Angular yield of both proton groups from $Li^{6}(d,p)Li^{7}$. R. W. Krone and others. bibliog diags Phys R 80:603-7 N 15 '50
Bombardment of Li_2O and C by alpha-particles and deuterons. I. B. Berlman. bibliog Phys R 80:775-81 D 1 '50
Cross section for photo-disintegration of the deuteron at low energies. G. R. Bishop and others. bibliog diags Phys R 80:211-22 O 15 '50
Deuteron bombardment of C^{14}. E. L. Hudspeth and others. Phys R 80:643-6 N 15 '50
Forward scattering of 3.1-Mev neutrons by the deuteron. J. Sanada and S. Yamabe. Phys R 80:750 N 15 '50

Fig. 24. Page from Periodical Index

dex is very helpful to the student who needs to get an idea for a satisfactory research topic and to those who need to limit the scope of the subject they wish to investigate.

On page 353 is reproduced a page from the *Industrial Arts Index* which shows how information is handled. Let's take a single entry from it and see what it tells us. The following entry is the fourth under "Deuterons":

> Cross section for photo-disintegration of the deuteron at low energies. G. R. Bishop and others. bibliog diags Phys R 80:211-22 O 15 '50

This entry guides us to an article by G. R. Bishop and others entitled "Cross Section for Photo-disintegration of the Deuteron at Low Energies," which appeared on pages 211 to 222 of Volume 80 of the *Physical Review*, published October 15, 1950. It also tells us that the article contains a bibliography and diagrams.

Because of the need for conserving space, entries are highly abbreviated. In case you cannot identify the name of the magazine by the abbreviation, you will find a list of full names of magazines indexed along with these abbreviations in the prefatory pages of each volume of the index. Note that volume and page numbers for a reference are given together, with a colon separating the first from the latter. Some of the entries show a + after a page number. This mark means that the article is continued on the back pages of the magazine.

3. *Readers' Guide to Periodical Literature.* The *Readers' Guide* is a cumulative author-subject-title index to articles appearing in magazines of general interest. Like the *Industrial Arts Index*, it comes out in monthly issues so that up-to-date references may be found in it. Semiannually, or oftener, these monthly issues are cumulated. For the student researcher, this guide is valuable because it will guide him to articles written for a nontechnical audience. Such articles, as we point out in the chapter on writing the research report, are good for getting general knowledge of a topic on which research is being started.

4. *Art Index.* A cumulative author-subject index to a selected list of periodicals, the *Art Index* is of interest to the architectural engineer, the architect, and the ceramic engineer.

5. *International Index to Periodicals.* This is an index of highly specialized professional journals. Engineering subjects are of secondary interest.

6. New York *Times Index.* This index is useful for finding newspaper articles.

7. *Chemical Abstracts.* Brief descriptive summaries of articles in the field of chemistry and chemical engineering, from 1907 to present.

8. *Engineering Abstracts.* From 1900 to present.

9. *Science Abstracts.* From 1903 to present.

10. *Agricultural Index.* A guide to articles appearing in magazines devoted to agriculture.

11. *Union List of Technical Periodicals.* This work lists the periodical holdings of more than 200 libraries. Material not in your library can be located here and secured on interlibrary loan.

12. *International Catalogue of Scientific Literature* (1902—). An annual index to 17 scientific fields.

Bibliographies of Bibliographies

Sometimes what you want most may be information about what bibliographies are available in your field of interest. *The Bibliographic Index* (1938—), which is issued quarterly, will prove helpful.

The National Research Council has issued several good bibliographies of bibliographies.

Miscellaneous

There are a few items that can conveniently be lumped here under the heading "Miscellaneous." This heading is not intended to imply that they are unimportant.

1. *United States Government Publications: Monthly Catalog.* This guide is invaluable in finding out what has been published by government agencies. Copies of government documents are obtainable from the Superintendent of Documents, United States Government Printing Office, in Washington in case the library does not possess them.

2. *Bibliography of Scientific and Industrial Reports.* This bibliography is issued monthly by the United States Department of Commerce.

3. H. S. Hirschberg and C. H. Melinat, *Subject Index of Government Publications* (1947). A particularly useful tool in the initial phase of a research project.

4. *Official Gazette* of the United States Patent Office. This publication provides information on patents issued. It is essential in much original research.

Encyclopedias and Dictionaries

Encyclopedias and other special reference works are generally not essential basic sources of information for a research report but they are often extremely useful to the researcher in the course of his work on a subject. Encyclopedias may provide him with needed general information to enable him to read books and articles with greater understanding. Special engineering and scientific reference works, as well as technical dictionaries and biographical reference books, may be just what he needs to find out about difficult points which arise during the course of his reading. The following are the principal works you ought to know about.

ENCYCLOPEDIAS. 1. *Encyclopedia Britannica.* A general encyclopedia, commonly regarded as the best in English. The 14th edition is in 24 volumes, supplemented annually with revisions and new information.

2. *Encyclopedia Americana.* This encyclopedia is regarded as especially useful on technical, business, and government topics. It contains maps, illustrations, and selective bibliographies.

3. *Van Nostrand's Scientific Encyclopedia.* A one-volume reference work (2d edition, 1947), very useful for its short articles on topics in all branches of engineering and science.

4. *Hutchinson's Technical and Scientific Encyclopedia.* In four volumes, this reference combines the functions of an encyclopedia and a technical dictionary.

DICTIONARIES. 1. *Chambers' Technical Dictionary.* This book, revised and supplemented in 1948 by C. F. Tweney and L. E. C. Hughes, is the best all-around technical dictionary.

2. Newmark's *Illustrated Technical Dictionary.*

3. Crispin's *Dictionary of Technical Terms.* The subtitle points out that this book defines terms commonly used in aeronautics, architecture, woodworking, electrical and metalworking trades, printing, and chemistry.

4. Henderson's *Dictionary of Scientific Terms.* Revised and enlarged by John H. Kenneth in 1949, this book is chiefly devoted to the biological sciences.

Biographical References

Besides the well-known *Who's Who in America* and the *Dictionary of American Biography*, the technical man finds the following of use:

1. *American Men of Science*
2. *Who's Who in Science*
3. *Who's Who in Engineering*

Leads to Trade Literature

In addition to the sources of information which you may find in a library, there is a vast amount of information published by industrial concerns in the form of bulletins, catalogues, reports, special brochures, and the like which can be of great usefulness. Most of these publications may be had free of charge by simply writing for them. The problem is to find out about them and to know where to write. Three books in the library may be of special value in solving this problem:

1. *Thomas' Register of American Manufacturers.* This two-volume work gives both an alphabetical and a classified list of American industrial organizations. Although it is designed as a purchasing guide, you can use it to find out where to write for information on special subjects.

2. *Sweet's Engineering Catalogues.* Commonly referred to as *Sweet's File*, this compilation of catalogues can also guide you to organizations which may be able to furnish you with information unavailable in your library.

3. *Printer's Ink Directory of House Organs.* House organs are magazines published by industrial organizations for circulation among employees, stockholders, and interested outsiders. This directory is a guide to these house organs, many of which are valuable sources of information. One example is *The Lamp*, a magazine published by the Standard Oil Company in a handsome format. It contains many articles of interest to the petroleum technologist.

Most of the official periodical publications of the engineering societies contain a column or so naming and describing new industrial bulletins, pamphlets, and the like.

Conclusion

It is almost impossible to overestimate the value of a thorough acquaintance with library resources, and yet it is not difficult to learn your way around a library once you recognize that doing so calls for deliberate and methodical study. The aids which have been noted in this chapter are by no means sufficient in themselves to solve all your future library research problems, but with these aids as a nucleus and with a genuine interest in the subject you will have no trouble in developing the knowledge that you will need.

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Writing the Library Research Report

Introduction

A study of technical writing that did not include the preparation of at least one report of four or five thousand words in length would be unrealistic. As you know, reports of this length, and indeed of much greater length, are common in industrial and research work. And there are some problems in writing a long report that are different from the problems of writing a short one, particularly in regard to organization and the handling of data. Furthermore, in an academic study of technical writing it is only in a fairly long report that you are likely to find a realistic synthesis or combination of writing problems you have previously been studying more or less in isolation.

These are good reasons for writing a long report. And usually the most feasible way of preparing a long report in a course in technical writing is to write a library research report.

The library research method itself may seem somewhat unrealistic, however, consisting as it does of study and discussion of what

other people have said about a subject. This method does not require you to wrestle with a mass of raw data, as was usually required of the workers whose books, articles, and reports you would read in the library. This is a serious disadvantage. But in most respects the library research method is quite satisfactorily realistic. The problems of style, over-all organization, format, handling of transitions, and so on, are not different from what you will encounter in a report on original work. Moreover, the writing of library research reports is often required in science and industry—not to mention advanced courses in college. When a new technical project of any kind is begun, one of the first tasks to be accomplished is frequently a search for everything in print that may have some bearing on the subject; and the results of such a search are usually written up in the form of a report, or used as the basis for a portion of a report.

Two other factors connected with the preparation of a library research report deserve mention. One is that it provides an excellent opportunity for increasing your knowledge of how to use the library. A second is that it may comprise an unusual opportunity to study in detail some technical subject that you would like to know more about. Students sometimes find the preparation of such a report a first step toward mastery of a special subject; and such specialized knowledge is often helpful in securing a position. Numerous students, within our own knowledge, have shown prospective employers a report of this kind as part of the evidence of their fitness for a job.

Considered as a process, the library research report requires the following steps: (1) selecting a subject, (2) making an initial, tentative plan of procedure, (3) finding published materials on the chosen subject, (4) reading and taking notes, (5) completing the plan, writing the rough draft, and providing the documentation, and (6) revising the rough draft and preparing the completed report. These steps will be discussed in the order stated, with the exception of step (3) to which the preceding chapter was devoted.

Selecting a Subject

In selecting a subject for your long report you should look for one that has the following qualifications: (1) the subject is interesting to you, (2) it is related to your major field, (3) it is a subject about which you already know enough so as to be able to read intelligently but not one about which you have nothing to learn, (4) it is restricted enough in scope so that it can be treated adequately within about 5000 words, and (5) it is a subject on which sufficient printed material is available to you.

Most of these qualifications are self-evident and need no particular comment. In regard to the last of them we would suggest this caution: don't assume that any library book or article or other document will be available for you unless you have it in your own possession. You may find that a highly important article is off at the bindery, or lost, or charged out to an uncooperative faculty member. One other point in the list above—the problem of scope—will be discussed at length in a moment.

The five qualifications listed can in general be met by three different kinds of subjects: (a) subjects representing a project you are actively working on, like building a boat, designing a gas model airplane, or remodeling a room in a residence; (b) subjects concerned with the making of a practical decision, like choosing the best tape recorder within a given price range, or the best outboard motor, or the best type of foundation for a given residence at a given location; (c) subjects you would like to study simply for curiosity's sake, like cross-wind landing gear for aircraft, offshore drilling platforms in the Gulf of Mexico, or rammed-earth construction for small homes. Which one of these three types of subject matter is the best for you depends on your interests and your background.

You will find it helpful to make a list of possible choices under each of the three headings, as one of the first steps in making your selection. As the next step, go to the library to find out whether sufficient material is available on the most attractive subject on your list. Right at this point, however, there is a strong possibility that you will run into the problem of limiting the scope of your subject. Chances are that your first formulation of the subject will prove too broad for a report of the length required. In order to make some suggestions about what to do, we'll consider an exaggerated example.

Suppose you are interested in the subject of television and decide that you will write a report on it. You consult the card catalogue and the appropriate indexes to periodical literature in the library and discover scores of articles and books which deal with television. Obviously you cannot read them all. Even if you could, you would find from an examination of titles that they deal with so many different aspects of the subject as to make unification of the material next to impossible. Further examination would show that much of the material is superseded by later developments and so is of no value. But the main thing would be the impossibility of covering all the material available. Two courses are open: you must reject the subject of television entirely or limit your investigation to some particular phase of it.

Assuming that you are unwilling to give up the subject altogether because of your interest in it, you will find several opportunities for limiting the scope of the subject. Let's consider just a few. You might begin with a time limitation and see what has been published on television developments during the last few years. It would quickly become evident that, for this subject, this way of limiting the subject would be wholly inadequate. So you might try subdividing according to subject matter rather than time. Here the classifications in the card catalogue and indexes would be of service. For instance, you might find a number of articles devoted to various parts of television apparatus, such as antennas, amplifiers, or cathode-ray tubes. Or special broadcasting problems might prove of interest, such as the feasibility of the use of aircraft relay stations. In short, examination of the titles of publications on the general subject in which you are interested should suggest any number of ways of limiting the subject to manageable proportions. Ultimately, of course, you must examine the publications themselves to be absolutely certain that they offer adequate but not too abundant material for a report of the length you are expected to write. But most of the work of limiting the scope of a subject can be done by careful thought to begin with and by careful study of available sources of information.

In general, subjects of relatively current interest are best, subjects that for the most part are treated in periodical articles. If whole books have been devoted to a subject, it is likely to be too broad for report treatment. This does not mean, of course, that books may not be used as sources of information. To return to our illustration above for a moment, we could be fairly certain of finding books on television in which chapters might be devoted to antennas, and these would be useful for a report on antennas. If we were to find, however, that an entire book or several books had been written on antennas, we should probably decide the topic is too broad for adequate treatment in a five thousand word report.

Making an Initial Plan

Once a subject has been chosen and approved by your instructor, it is time to lay a few plans for general organization and coverage of the subject, so as to simplify and give direction to the task of reading and taking notes.

First, make a list of the things you want to find out about your subject. To this list, add those things you think your reader will want to know. Sometimes these items will be identical, sometimes not. This list will prove most useful to you when you read and take notes: you

will have some idea of what to look for in the reading. Of course, it will undoubtedly prove necessary to revise the list, perhaps a number of times. You may discover, for instance, that nothing has been published on some particular aspect of the subject which you thought ought to be discussed. You may discover important aspects of the subject discussed which had not occurred to you when making your tentative, guidance outline. You may discover that certain aspects of a subject will have to be eliminated because of space limitations. Such a list or outline should not in any sense be regarded as final but merely as a general guide, something to give you a sense of direction, so to speak, and subject to change at any time.

If, however, your knowledge of a chosen subject is so slight to begin with that you do not feel able to compile such a list, you should do some general reading on your subject first in order to acquire the necessary acquaintance with it. Then you can make a tentative outline. The importance of making a list for guidance will be made clearer in the discussion of note taking.

An example of the relation of an initial list of topics for guidance to a final report outline is shown below. The subject was the magnetic fluid clutch.

Initial Guidance List

1. What functioning parts does it have?
2. How does it operate?
3. How much does it cost to make?
4. How efficient is it?
5. Is it difficult to maintain and repair?
6. When was it developed and by whom?
7. How does it compare with other types?

Final Outline

I. Introduction
   A. Definition of a clutch
   B. The need the magnetic clutch can fill
   C. Object of this report
   D. Scope and plan of this report

II. Principle of operation

III. Description of clutch
   A. Driving assembly
   B. Magnetic fluid
   C. Driven assembly
   D. Electric coil

IV. Advantages and disadvantages
   A. Inertia
   B. Simplicity of design
   C. Leakage
   D. Ease of control
   E. Number of parts
   F. Smoothness of operation
   G. Fluid trouble
   H. Centrifugal trouble

V. Applications
   A. Automotive
   B. Servo-mechanisms

Reading and Taking Notes

Once a preliminary list of sources (bibliography) has been compiled and a guidance list has been set down, it is time to begin reading and taking notes. In deciding what to read first from a list of sources, you should choose a book or article which promises to give a pretty general and complete treatment of the subject and to be simply and clearly presented. How a book or article rates in these qualities can be guessed at by examining titles and places of publication. For instance, an article entitled "Color Television Explained" appearing in a magazine like the *Saturday Evening Post* is certain to be easy to understand and nontechnical in its treatment. By reading simply written articles covering your subject broadly, you will be better able to understand and use the information you find in books and specialized periodicals. It may happen that your judgment of a title and place of publication will turn out to be wrong, but in general you will simplify your job by following this procedure.

You can now begin reading and taking notes. This is a job that should be highly systematic from the start. The following paragraphs will outline an efficient method.

Three basic requirements of any good system of reading and note taking are (1) the reading should be conducted according to a plan, not haphazardly; (2) the method of arranging the sequence of the notes should be highly flexible; and (3) the system should be economical of time.

The first of these three requirements has already been discussed. Its observance required the preparation of an initial guidance list or outline so that pertinent materials can be selected and irrelevant materials ignored. We can go on, then, to discuss the second and third requirements.

Flexibility of arrangement of the notes is easily achieved by the use of cards. In theory, the method requires that only one note be written on a given card (4 by 6 cards are a convenient size). It is next to impossible to define "one note," of course. For the purpose of our discussion, however, it will be sufficient to say that one note is any small unit of information that will not have to be broken up so that the parts can be placed at separate points in the report. When all the note cards have been prepared and arranged in the proper order it should be possible to write the report without ever turning forward

or backward as you go through the pack of cards. Naturally, such perfection is scarcely to be expected in practice.

There are several symbols or labels that can be used to save time. The first of these is a heading, put at the top of the card (see Figure 25). This heading is useful in the process of sorting and arranging the cards. It can be taken from the tentative outline. Some people like to add a symbol from the outline (like II A).

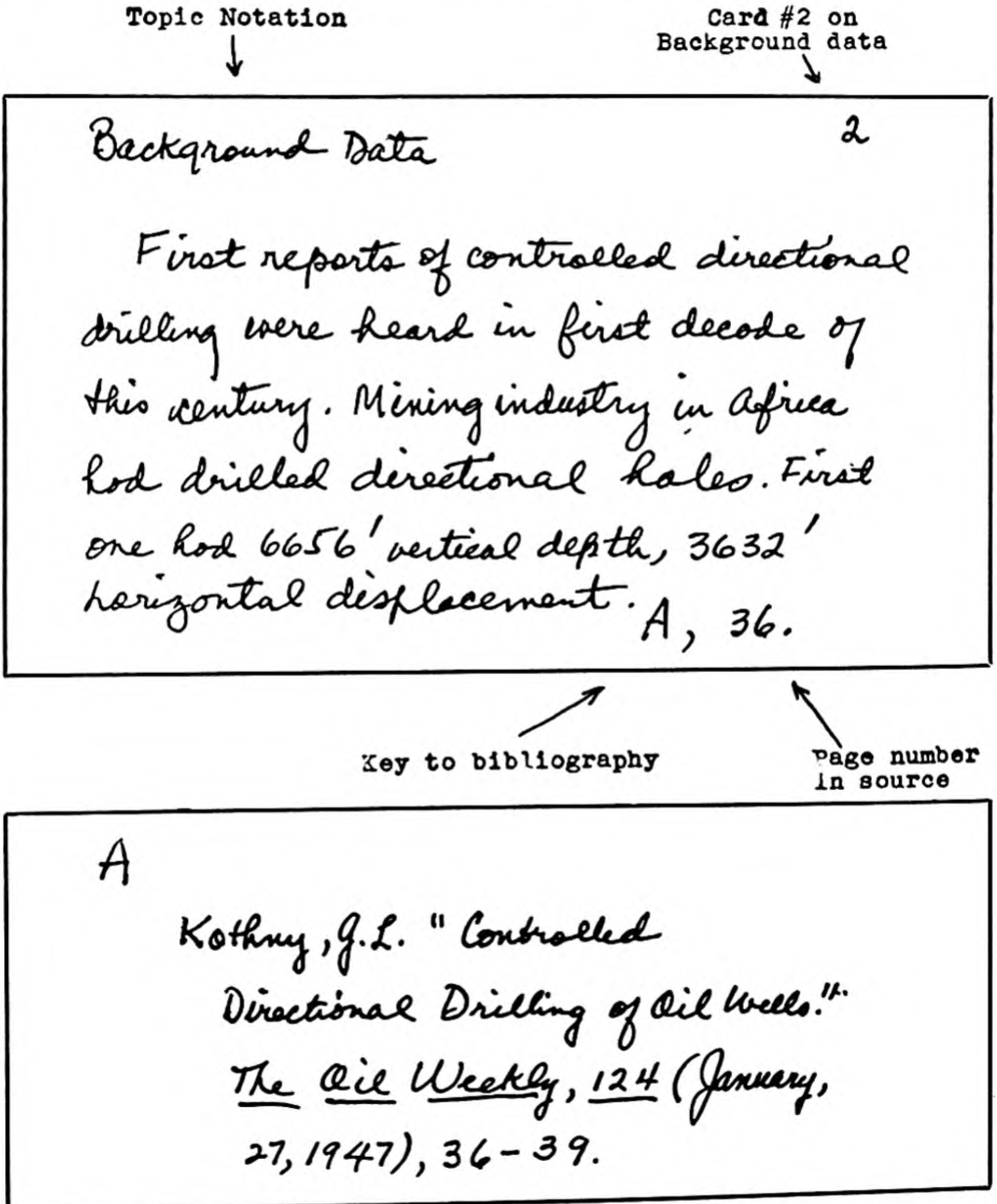

Fig. 25. A Note Card and a Bibliography Card

Secondly, it is convenient to use a symbol to indicate the source from which the note was taken. It is imperative that you indicate the source of every note, so that the text can be properly documented. One way to keep a record of sources would be to write complete bibliographical data on each note card. This method would be inefficient, however, whenever you had more than two or three note cards from the same source (imagine writing eight or ten times the data for an article with a long title from a journal with a long title, and written by two or three people).

A better way is the following. Write the bibliographical data on a blank card. You may find it helpful to use a card of a different size from the note card, or a different color, so that it is easy to distinguish the bibliographical cards from the note cards. On this bibliographical card, put a capital letter in the upper left-hand corner. Now, whenever you make a note from this source, instead of writing the complete bibliographical data on the bottom of the note card, all you need do is write the capital letter that will key the note card to the proper bibliographical card.

The last entry on the note card is the number of the page from which the information in the note was taken. This is shown in Figure 25.

One thing we have not yet mentioned is the nature of the notes themselves. In other words, what kind of note should one make—an outline, a series of words and phrases intended to recall complete discussions, full almost word-for-word transcriptions, or what? Our advice is that your notes should first of all be entirely in your own words (except for quotations, about which we shall say more in a moment) and in summary form so far as possible. Secondly, we strongly recommend that notes be made full enough so that you will not be confused as to their meaning and significance later on when you come to use them. It is important to avoid using the same phrasing and sentence structure that the author of the article uses. To make the material your own, you should first read it carefully, making sure you understand it, and then put down what you want to use, briefly and in your own words. We would emphasize the importance of economy of words in note taking, to simplify the job of studying and using the notes later on. It is quite discouraging to read a note, perhaps some weeks after it was made, only to discover that it does not make sense to you and that you have to return to the source in order to find out what you had tried to get down in your notes.

Direct quotations are not essential to a research report, but there are several reasons why the writer of a research report may wish to

quote the words of an author directly. First, he may want to lend force and emphasis to a section of his report by quoting a well-known authority. Second, he may feel that the statement of an original idea deserves to be presented in the originator's own words. Third, he may feel that an author has stated a point in such a way that inclusion of the original will enhance the interest of his own report. Fourth, he may wish to reproduce an author's opinion on a topic. Whatever the reason for a quotation, it is essential that the quotation be absolutely exact. Quotation marks should be placed around it in your notes, and a notation of page number made.

In concluding this discussion of note taking we should like to urge you to remember that the system we have described is not a magic formula. You will have to use intelligence at every step, and you will inevitably have to do a lot of work with the cards, discarding repetitious notes and filling in gaps. On the other hand, the system is efficient. It comes closer than any we know to satisfying the three basic requirements stated at the beginning of our discussion. And its advantages are attested by the fact that it is widely used.

Completing the Plan and Writing the First Draft

Once you have completed taking notes, it is time to prepare a final outline of the organization of your report. To do this properly, you will have to read through your notes carefully, perhaps a number of times. First of all, you will want to make yourself thoroughly familiar with the content of your notes so as to be able to write about your subject naturally and clearly. And while you are mastering the content of your notes, you will be devoting some thought to the best order in which to present the topical divisions of your subject matter. It is at this stage that the usefulness of the note-taking system just described becomes most apparent. With topic headings on each card, you can now rearrange the cards in the order in which you think the contents should be presented. This rearranging may call for several experimental tries before you are satisfied with the result.

When the above preliminaries have been carried out, writing the rough draft amounts to little more than transcribing your notes to paper in a connected, coherent discussion. They will not be transcribed verbatim, of course. Although your notes, if properly taken, will be in your own words rather than in those of the authors of your sources, as an additional safeguard against reflecting the style of writing used in your sources you will do well to rephrase and reword many of the passages in your notes. You will do a good deal of this anyway (that is, without making a conscious effort) if you have mastered the

content of the notes thoroughly. Furthermore, you will be adding transitional statements, developing and clarifying some points of fact by supplementary discussion, making comments (evaluations and conclusions) about the facts from your sources, and the like. In short, the report itself will contain a good deal of writing that is yours, personally, and not merely transferred from a source to your paper.

Most inexperienced writers attempt to do too much when they undertake the first draft of a report; they try to devote attention not only to the subject matter itself but also to style and correctness of expression. In writing the first draft, forget about style and correctness. Concentrate on the subject matter alone. Get down on paper what you want to say; there will be time later for smoothing out your sentences, correcting your spelling, punctuation, and choice of words. If you have a lot of inertia to overcome in getting started with your writing, do not conclude that you have no talent. Most writers are slow in getting started, even professional ones. Once a start is made, however bad, the task usually becomes easier. Awkward beginnings can be remedied later on.

Documenting the Report

Documentation is the recording of published source materials for the research report. Sources are recorded in two forms: (1) a bibliography which appears at the end of the report, and (2) footnotes which appear throughout the report at appropriate places. A bibliography is included in the report because it is a convenience for the reader to have all the source materials listed in one place, and because the presence of the bibliography makes it possible to use simpler footnote forms in the text than would otherwise be possible. Footnotes are included to satisfy the ethical obligation of a statement of indebtedness, and to make it possible for the reader to check the authenticity of the text or to find additional information.

THE BIBLIOGRAPHY. The bibliography is an alphabetized list, according to authors' last names, of all the written sources you have consulted—books, magazine articles, pamphlets, bulletins. Since you will already have a card for each of your sources with the necessary bibliographical information on it, making the formal bibliography is simply a matter of listing the items in proper order and recording the entries in correct form. For a book or independent publication (not appearing in another publication), such as a booklet, you need to put down, in order, the author's name (surname first), the title (along with data pertinent to it), the place of publication, the publisher's name, and the date of publication. Here are some typical examples:

Francis, Wilfred. *Boiler House and Power Station Chemistry*. London: Edward Arnold and Co., 1940.

Gaum, C. G., Harold F. Graves, and Lyne S. S. Hoffman. *Report Writing*. 3d. ed. New York: Prentice-Hall, Inc., 1950.

Pigman, G. L., and Thomas M. Edwards. *Airline Pilot Questionnaire Study on Cockpit Visibility Problems*. Technical Development Report No. 123. Indianapolis, Ind.: Civil Aeronautics Administration, 1950.

The second item above shows how to present multiple authorship and data about edition. The third item was printed in booklet form.

Be careful about the form of bibliographies. Notice that a period follows each element: authorship, title, and publishing data. Each entry is single-spaced. The first line begins even with the left-hand margin; additional lines, if needed, are indented five spaces. There is double spacing between entries.

The same general form is used for magazine article entries: authorship, title, and publishing data. The publishing data include the name of the magazine, the volume number of the magazine, the date of publication of the issue in which the article appears, and the page references. Study the following examples:

Abbott, John. "Wood as an Insulator." *Dielectric Review, 55* (January, 1951), 15-17.

King, Robert. "Technology—Today and Tomorrow." *Scientific American, 182* (May, 1951), 56-76.

"New Atomic-Powered Submarine." *Time, 28* (August 29, 1951), 56.

Notice that a period follows each main element of the entry, just as in an entry for a book. The title of the article is enclosed in quotation marks; the title of the periodical is underscored on the typewriter. The underscored number given just before the date of issue is the volume number of the magazine. It is underscored to distinguish it from the page number which follows the date. The last item above shows what to do with an article for which no authorship is given. Enter it alphabetically according to the first important word of its title. Many magazines print articles by staff members without the signature of the author. As a matter of fact, it is often true that a number of people on the staff of a periodical have had a hand in the authorship of an article. This is especially true of news magazines, like *Time* or *Oil and Gas Weekly*. If an article is labeled "Anonymous" in the magazine in which it appears, it should be so labeled in a bibliography, of course.

Oftentimes the question arises as to whether an article read but not made use of should be listed in the bibliography. As we have noted before, the researcher often finds several articles containing sub-

stantially the same information. If he has made notes on the first of these articles, he will not have taken notes on the others. Should he list them in his bibliography? The answer depends on whether the bibliography is to be regarded strictly as a list of sources actually made use of for facts within the report, or a list of articles which bear upon the subject. Our feeling is that only those published materials which have been made use of in writing the report should be listed. On the other hand, it certainly is defensible to list all sources dealing with a subject which have been read, whether or not all of them furnished data which are ultimately incorporated into the report. Perhaps your instructor will have an opinion on this matter by which you can be guided.

THE USE OF FOOTNOTES. And now we come to the problem of footnoting the report, that is, the problem of writing notes at the bottom of pages to acknowledge indebtedness for facts and ideas presented in the discussion. Later we shall illustrate the form and content of various kinds of footnotes but first let's clearly understand what needs to be footnoted. In other words, when do you need to write a footnote? The answer is simple: every fact, idea, and opinion which you have secured from your reading, quoted or paraphrased, must be acknowledged in the form of a footnote. Although footnoting may seem like an alarmingly difficult task at first thought, it really isn't so very difficult. Remember, your first draft has been largely a transcription of your notes, and your notes contain precise indications of the source and page number of each fact. You can, of course, put footnotes into your report during the process of writing the first draft. Or you may wish to wait until you have finished getting your discussion down on paper. It doesn't really matter when it is done. The important thing is to do it, and do it completely.

A number of questions naturally arise. Suppose one sentence contains information from two or more sources—does this call for only one footnote, or for more than one? On the other hand, suppose several pages of discussion in the report are based on a single source—does a footnote need to appear after each sentence, each paragraph, or at the end of the discussion?

Every unoriginal statement must be documented. That means two footnotes must be written if a single sentence contains data from two distinct sources. If a paragraph contains information from a dozen sources, a dozen footnotes appear at the bottom of the page. If several pages are based on one source, just one note is needed, at the end of the discussion. To put it another way, a footnote must appear at the end of each portion of discussion which is based on a particular source.

The portion may be a phrase, a sentence, a paragraph, or a longer part of your composition. Let us repeat, your notes will have each fact identified as to source and page number. Except for the work involved, there will be no difficulty in documenting each fact.

"But suppose," you may say, "that in between two paragraphs of information taken from sources appears a paragraph which is original, like an evaluative comment, or a transitional paragraph. Do I need to footnote that?" The answer is no; you do not need to footnote yourself. "But," you may object, "how will the reader know that what I am saying is original and not taken from one of my sources? Perhaps he will think I've simply forgotten to put in a note." The answer to that is: the reader can usually tell from the nature of the comment that you are advancing—its content and style—that it is you speaking, not one of your sources. We say he can "usually" tell; it is quite possible, to be frank, that he cannot always tell. To be foolproof, footnotes would probably have to accompany every statement in your report, including those which you make on your own. But this would be silly. Just remember to document all of the facts you have secured in your research, all the information you acquired *after* beginning your investigation, and you will have done a satisfactory job of documenting your report.

Although the foregoing discussion may make it appear that you will of necessity have an extremely large number of footnotes in your report, it doesn't usually take nearly as many as you might think. Let's consider for a moment an actual case. One of our students wrote a report entitled *Tantalum as an Engineering Material*. He organized it according to the following main headings: Introduction, Occurrence, Extraction of Tantalum, The Working of Tantalum, Tantalum Alloys, Uses for Tantalum, and Costs of Tantalum. His bibliography contained fifteen items. His report, which was twenty-one pages long, contained only thirty-two footnotes.

Here's how they were distributed. None was necessary for the introduction because in this section he simply introduced the reader to tantalum as one of the rarer metals and explained what he proposed to discuss in the remainder of the report; he explained the purpose of the report, its plan of presentation, its limitations, and its point of view. Section II contained eight footnotes, five of them references to one source. It happened, you see, that most of his information on the occurrence of tantalum came from a United States Bureau of Mines article entitled "World Survey of Tantalum Ore." The other three articles referred to in this section had provided him with bits of information not contained in the above-mentioned item. He could have

got by quite adequately with four footnotes instead of eight for this section in view of the fact that most of his data came from the one source. The third section of his report, on the extraction of tantalum, was based on information from one source, and he used two footnotes, one for each of the two paragraphs in this section. He could have used just one note. The fourth section, on the properties of the metal, contained seven footnotes, all but two of them references to one source. This one source contained the most complete discussion of the properties of tantalum; the other two articles referred to gave him a few facts not contained in the chief source. Here again he could have reduced the number of footnotes from seven to three or four. His fifth section, on the working of tantalum, contained eight footnotes, six of them from three sources. In general, separate subdivisions of this section were based on different sources so that he found it necessary to put a footnote at the end of each topical subdivision of the section, plus an additional one for a direct quotation. The next to last section, on uses for tantalum, required four footnotes—he had found material on four uses in four different articles. The last section, on costs, contained two notes.

The ratio of report length to number of footnotes described above is fairly typical but no particular significance should be attached to the example. Another report of the same length might contain twice as many footnotes, or half as many. It all depends on how many sources are used and the extent to which each is used. You should not use more footnotes than are needed, but you should use enough to make clear the source of all information secured during the process of investigation.

The method of footnoting just discussed provides for complete documentation of the content of the report. Some people, however, feel that a somewhat less demanding and rigorous attitude toward the need for footnotes may be taken. They feel that facts which are common knowledge to workers in the field in which the research subject falls do not need to be documented, even though they may have been new to the writer at the time he began research. This would mean that footnotes would be necessary only for (1) direct quotations, (2) controversial matters, (3) ideas of critical importance in the content of the report, (4) citation of well-known, authoritative writers, (5) acknowledgment of an author's originality in developing the idea presented, and (6) comments on additional material the reader might like to examine.

Although footnotes are primarily used for references to sources in a research report, they do have other uses. Definitions of technical

terms used in the text may be put in the form of footnotes if it is felt that some readers may need the definitions. Of course, if a term is one of crucial importance, its definition should appear in the text. But it may happen that a number of terms need to be used which may or may not be familiar to a reader; the writer will not want to interrupt his discussion repeatedly to supply definitions, and footnotes offer a satisfactory solution. Footnotes may also be used for other statements which the writer feels do not properly belong in the discussion. Suppose, for instance, that you find all your sources but one in agreement on some point in your discussion. A footnote could be employed to report on this one exception to general agreement. Finally, let us say that footnotes should be kept to a minimum; although necessary for acknowledging sources of information and occasionally for supplementary discussion, they do constitute an interruption to the reader and certainly add nothing at all to the readability of reports. Do not put a lot of them into a report in the hope that they will make it more impressive.

THE FORM OF FOOTNOTES. Knowing when and what to footnote does not completely solve the problem of documentation. We have yet to consider the form of the notes. We shall describe what we consider to be a satisfactory form for various kinds of footnotes, but we must frankly say to begin with that no single standard exists among professional scientists and engineers for documentary forms. In general, professional societies, research organizations, and editors of technical periodicals do agree on what information should appear in a bibliography and in a footnote, but they by no means agree on the form this information should be put in. While a standard would in some ways be desirable, the absence of one does not constitute a serious problem. Our advice is to try to find out what form is preferred by the person or organization to whom you are going to submit the report. If no specific form is preferred, make use of the form described in this book. The important requirements of documentary forms are that they be accurate and complete enough so that the reader could locate the source should he wish to, and as brief as possible consistent with the above requirements.

When a bibliography is presented at the end of a report, as we suggest for the library research report, footnotes may identify sources as briefly as possible. If no bibliography is appended, first footnote references to sources must be complete. In discussing the form and content of footnotes, we shall assume that a complete and formal bibliography is to appear at the end of the report.

A first reference to a book source should contain the author's sur-

name, the title of the book (underlined), and the page reference, with commas after the author's name, the title, and a period at the end of the note. If you have read articles by different writers with the same surname, you will have to preface the surname with initials. The same form is used for references to magazine articles except that the title of a magazine article is enclosed in quotation marks rather than underlined. The comma after a magazine title comes inside the last quotation marks. Thus two notes, one to a book and one to a magazine, would appear as follows on the first reference to either source:

[1] Jones, *Color Television*, pp. 19–21.
[2] Smith, "New Color Television System," pp. 12–14.

Compare these with the following bibliographical entries which would have to be made for each:

Jones, H. B. *Color Television*. New York: Rinehart & Company, 1951.
Smith, T. S. "New Color Television System." *Electronics Review*, *31* (February, 1950), 10–20.

Subsequent references to the same sources may be presented more briefly. If either of these sources is referred to again later in the report, the footnote need contain only the name plus the new page reference, as:

[7] Jones, p. 18.
[8] Smith, p. 15.

Obviously, however, if you have used two or more publications by the same author you will have to include the title in every footnote to avoid confusion.

If subsequent references to the same source are consecutive and on the same page, the abbreviation *ibid.* (for *ibidem* meaning "in the same place") may be used, along with the proper page reference if it differs from its immediate predecessor. This abbreviation does not represent much saving of time and effort if it is used in reference to a source with a single author; it does save time if there are several authors for an item. Compare:

[5] Gaum, Graves, and Hoffman, p. 20.
[5] *Ibid.*

Incidentally, the first of the above illustrations could be written "Gaum and others."

The above illustrations are for simple book and magazine article references, but the forms are suitable for references to practically any printed source of information. Remember that the title of any pub-

Dr. St. Clair reasons that:

> These acoustic forces, arising from radiation pressure, act to cause a concentration of the suspended particles in the regions of maximum displacement and to produce attractive and repulsive forces between the particles.[19]

Variables to Consider

Three variables must be considered in connection with the precipitation of aerosols in large industrial volumes: the sound field intensity in which the aerosol is treated, the exposure time, and the frequency of the sound.[20]

Intensity. Although noticeable agglomeration is caused at 140 decibels, an intensity of about 150 decibels is most efficient for industrial applications.[21] Sounds above 120 db, incidentally, are painful to the human ear.[22]

Effective conversion of the energy of a generator to sound depends upon the design of the generator and treating chamber. A properly designed installation may convert 40% to 60% of the compressed gas's energy to sound energy.[23]

19St. Clair, "Agglomeration of Smoke, Fog, or Dust Particles by Sonic Waves," p. 2439.

20Danser and Newman, "Industrial Sonic . . . ," p. 2440.

21Ibid., p. 2441.

22Jones, Sound, p. 245.

23Danser and Newman, p. 2440.

Fig. 26. Illustration of Page with Footnotes

lication which is published as a separate unit is underscored, and that titles of items which appear within another publication (which has a covering title) are enclosed in quotation marks. Thus the title of an advertising leaflet of no more than a half dozen pages would be underlined. The title of an article in an encyclopedia would be enclosed in quotation marks, but the title of the encyclopedia would be underlined.

Some additional details of mechanical handling of footnotes in a report are as follows: (1) number footnotes consecutively throughout your report with Arabic numbers raised slightly above the level of the line (they are called superscripts); (2) type or draw a heavy line part or all of the way across the page between the last line of the text on the page and the first of the footnotes; and allow at least two spaces above and below this line—you don't want the last line of text to appear to be underlined; (3) place the superscript numbers after the word, paragraph, section, or quotation in the text to which they refer, and do not put any mark of punctuation after them; (4) indent the first line of a footnote five spaces but begin additional lines even with the left-hand margin; (5) single-space a footnote of more than one line but double-space between separate notes; (6) in a footnote the name of the author need not be repeated if it has already been given in the text (if you have written, "John Doe says in a recent article . . . ," you need not repeat John Doe's name in the footnote giving title and page). The sample page (Figure 26) from a student report illustrates most of the details.

The foregoing discussion makes no attempt to be complete. Although the form described is satisfactory for most references, there are numerous special problems that may arise. You should consult your instructor in working out a solution to them. For knowledge of reference forms employed by publications in your professional field, consult the official publications of the professional societies. (The American Society of Mechanical Engineers, for instance, publishes a style manual; the American Institute of Electrical Engineers distributes a booklet entitled *Information for Authors.)*

Revising the Rough Draft and Preparing the Final Copy

After the rough draft has been completed, the next step is to revise the rough draft and prepare the report for submission. We shall assume that the documentation has been done on the rough draft. We suggest that you plan your work so that you will have plenty of time for the revision. As a matter of fact, it is an excellent idea to al-

low enough time so that you can lay your rough draft aside and forget it for several days, perhaps a week. The reason for this suggestion is that you will have difficulty spotting your mistakes if you undertake revision immediately after finishing the rough draft. See page 253 for an illustration of the kind of error too-hasty revision may produce. You want to be able to read your rough draft objectively and critically, putting yourself as much as possible in the place of the person or persons who will read the finished report.

You can use the time between writing the rough draft and revising it to clean up other tasks incident to completion of the report: preparing the illustrations, preparing the cover and the title page, the letter of transmittal, the table of contents, the list of figures, and writing a first draft of the abstract.

As you start the final revision of the report, remember that you are making a revision, not a final copy. Making the final copy should be a purely mechanical operation, involving no significant changes in the text. If you try to make revisions and final copy simultaneously, you will find yourself involved in such troubles as making a change on page ten that in turn requires a change on page five—which is already typed!

After you have completed the revision of the report, it is wise to go through it again several times, from cover to cover, deliberately checking each time for only one or two specific elements. Certainly the entire text should be checked once for grammar, with special attention to dangling phrases, pronoun reference, and subject-verb agreement; once for transitions; and once for spelling if you have trouble with spelling. We know a professional engineer who says he reads his reports through backward to check the spelling! He claims that by going backward he avoids getting absorbed in the meaning and finds it easier to catch misspelled words.

Just what elements should be checked depends to a considerable extent upon the material involved and your own strengths and weaknesses as a writer. The Report Appraisal Chart which we have included may be helpful. To this chart we would strongly recommend that you add the following questions:

1. Are all the necessary functions performed by the introduction and the conclusion or summary?

2. Are transitions properly handled?

3. Are the principles of the special techniques of technical writing, like description of a process, observed as such techniques are required in the text?

Methodical use of a check list is good insurance. If you can answer "Yes" to all the questions in it, you can turn in your report confident that you have done your best and reasonably assured that you have done well.

Report Appraisal Chart

The chart on page 378 is intended to assist you in planning, writing, and editing your own reports or in indicating to others the specific weaknesses of reports submitted to you for editing.

Before appraising a report, be sure to determine its exact purpose. What response is desired from the reader—or readers?

Suggestions for Research Report Topics

The choice of a subject for a library research report should be made in accord with the principles explained in this chapter, the extent of the resources of the libraries accessible to you, and the advice and approval of your instructor. The following list of topics is simply intended to be suggestive.

Anti-icing Devices for Aircraft
Use of Aluminum in Bridge Construction
Production of Monosodium Glutamate
Soil-Cement Stabilization of Roads
Recent Developments in High-Compression Engines
Liquefied Petroleum Gases for Internal-Combustion Engines
Solar Heating for Small Homes
Nickel-Cadmium Batteries
The Heat Pump Water Heater
Laminated Wood Arches
Stall Warning Devices in Aircraft
The Problem of Dampness in Dwellings
Ultrasonic Precipitators
Production and Uses of Tantalum
Printed Electronic Circuits
Aircraft Refueling in Flight
Gas Turbines for Automobiles
Use of Commercial Diamonds in the Petroleum Industry
Air-Entrained Concrete
Use of Plastics in Oil Wells
Prestressed Concrete

CAN YOU ANSWER "YES" TO THE FOLLOWING QUESTIONS?

IS THE REPORT

1. COMPLETE
   a. Does it give all information necessary to accomplish its purpose?
   b. Does it answer fully all questions likely to be in the reader's mind?
2. CONCISE
   a. Does the report include *only* the essential facts?
   b. Are the ideas expressed in the fewest words consistent with clearness, completeness, and courtesy; have irrelevant details and unnecessary repetition been eliminated?
3. CLEAR
   a. Are all facts arranged in proper sequence; are they directed to the interest of the reader?
   b. Is the language adapted to the vocabulary of the reader?
   c. Do the words exactly express the thought?
   d. Is the sentence structure clear?
   e. Is each paragraph one complete thought unit?
4. CORRECT
   a. Is the accuracy of all factual information beyond question?
   b. Are all statements in strict conformity with policies?
   c. Is the report free from: (1) grammatical errors, (2) spelling errors, (3) misleading punctuation?
5. APPROPRIATE IN TONE
   a. Is the tone calculated to bring about the desired response?
   b. Is the report free from antagonistic words or phrases?
   c. Is it free from hackneyed or stilted phrases which may suggest that our business methods are as outmoded as our language?
   d. Are the facts organized to hold the reader's interest and to *carry conviction?*
6. ATTRACTIVELY DISPLAYED
   a. Can the reader *readily* know the *purpose* of the report?
   b. Are the main parts easy to find: conclusions, recommendations, supporting data?
   c. Are headings, subheadings, underscoring, italics, tables, charts, and other devices for effective display used appropriately?
   d. Will the physical appearance of the page create a favorable impression upon the reader?

Figure 27. Report Appraisal Chart. Adapted by permission from Writing Effective Government Letters, *copyright 1939 by James F. Grady and Milton Hall.*

Appendixes

appendix a

A Selected Bibliography

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appendix b

The Galt Manuscripts

The manuscripts which appear in this appendix are presented so that you can study the process of revision. The materials include two versions of an oral report and two of a written report on the same subject—artificial refrigeration. The first version in each case is one of several rough drafts which were written by Mr. Galt. The second version in each case is the final one. Along with each version we have made editorial comments to draw your attention to some of the more significant differences between the two versions. We have presented versions of both the oral and written treatment of the subject in order that you may compare the techniques of these two forms of presentation.

These materials were prepared by Mr. John L. Galt, of the General Electric Company, for presentation in a contest sponsored by the American Institute of Electrical Engineers. They are reprinted here by permission of Mr. Galt. It may be of interest to you to know that Mr. Galt won the contest.

Version 1 of Galt Talk

Cold Facts

Mr. Galt realizes the importance of a good "lead" and here tries to capture the interest and attention of his audience at the very outset. He tries to do so by employing a common point of interest —the pleasure people get from speculating about what they would do with a lot of money. In this version, he develops his lead point by suggesting several possibilities—and he makes one of them humorous.

If you had a million dollars in your pocket, what would you do with it? The possibilities are unlimited, aren't they? You might go into the real-estate business, to the extent of 100 ten thousand dollar houses. You might buy 500 two thousand dollar cars and clean up a tidy little profit for a vacation in South America. I once knew a fellow who said if he had a million dollars he'd buy a half-dozen trainloads of peanuts. Some sort of a scheme on the order of the recent phenomenal developments in the soybean industry. That's what we all thought—but it wasn't that at all. He just liked peanuts.

In this second paragraph —still a part of the introduction—Galt leads into his subject matter proper —ice. The technique here is the startling fact—designed to fix attention.

Well, there was once a time when, if you had had a million dollars, you could have bought a ton of ice. Ice, that stuff you're getting so tired of scraping off your sidewalk. Ice, which is now being manufactured at a cost of less than half a cent per pound, less than ten dollars a ton.

The startling fact is explained in this paragraph.

You see, it hasn't been so many years that we've had artificial refrigeration and ice-making. In fact, as late as the nineteenth century, the summer supply of ice to the Southern states came from the North. It wasn't artificial ice, it was ice that had been cut from frozen lakes during the winter and packed away in sawdust. There were no railroads in the South then, so the ice was transported southward by means of waterways and oxcarts. It always sold at a very high price, but it was during the New Orleans yellow-fever epidemic of 1853 that ice sold for the fantastic price of 500 dollars per pound, to be used for crude air conditioning in sickrooms.

This paragraph and the next complete the process of introducing the subject matter proper.

Was there ever a more challenging problem facing the engineering ingenuity and resourcefulness of man in his struggle for independence from nature? He had long since developed reasonably satisfactory methods of

Final Version of Galt Talk

Cold Facts

THE STORY OF ARTIFICIAL REFRIGERATION

How many times have you sat in idle and pleasant speculation upon that characteristically American proposition, "Boy, what I couldn't do if I had a million bucks!"

Well, there was once a time, not so very long ago, when, if you had had a million dollars, you could have bought *a ton of ice—two thousand pounds of frozen water.* It was during the New Orleans yellow-fever epidemic of 1853; natural ice, transported from the North by oxcart and river barge, was at a premium for use in air-conditioning sickrooms. That ice was selling for the fantastic price of *five hundred dollars a pound—a million dollars a ton.*

Here was a problem challenging to the engineering ingenuity of man—the forcefully demonstrated need for *controlled cooling* in man's habitat. That problem has been admirably met by a handful of pioneers, from whose work has evolved the modern science of "refrigeration engineering." Let's take a look at some of the aspects of this science, now so commonly taken for granted.

First of all, we may define "refrigeration" as "a process whereby heat is transferred from a place where it is undesirable to a place where it is unobjectionable." This transfer involves two distinct problems: first, the *collection* of heat from the space to be cooled, and second, the *transportation* of the heat away from the space. We will consider the solution of these problems in connection with "vaporization refrigeration."

Vaporization refrigeration is based upon the following principles: One, the evaporation of a liquid is accompanied by the absorption of a large quantity of heat; the common example is the cooling of the human body by the evaporation of perspiration. Two,

In this version, Mr. Galt keeps his original lead idea, but pares it down by eliminating the suggestions which followed it in the original. By doing so, he gains emphasis, force, directness. Furthermore, he has cut the joke which, however funny it might be considered by his audience, would interfere with their grasping the really important point stated in the second paragraph.

The second and third paragraphs of the original become one here to give greater directness and force.

Rephrased for better emphasis, this paragraph usefully says, "Let's take a look. . . ." to tell the audience what it can expect to hear discussed.

Observe the shifting of the transition to "vaporization refrigeration" from the opening sentence in the first version to the previous paragraph here. The definition of vaporization refrigeration is clarified by the reference to perspiration.

"First of all" is a transition between the introduction and the body of the talk. The second sentence's opening ("This transfer") is clearer than the original's "It."

More than twice as long as the original, the explanations given here of evaporation and transportation are certainly clearer.

keeping himself and his house warm in the winter, but, other than ventilation, few means had been developed for his relief from heat.

The problem has been admirably met by the men from whose work has evolved the science now known as "refrigeration engineering."

In both this draft and the final draft, Galt uses sound technique by starting the main body of his discussion with a definition of the central topic—refrigeration—and by announcing the two problems involved.

"Refrigeration" may be defined as a process whereby heat is transferred from a place where it is undesirable to one where it is unobjectionable. It involves two problems, the *collection* of the heat, and the *transportation* of the heat away from the cooled space.

The explanation of evaporation and transportation of heat is given in technical terms in this draft. Compare it to the expanded, clearer final version where the more leisurely explanation gives the listener time to absorb the facts. This is a good example of "pace" in exposition. Brevity is not always to be equated with clarity .

We will consider "vaporization refrigeration," which is based on the fundamental principles that liquids, on vaporization, absorb large quantities of heat with no change in the temperature of the fluid, and reducing the pressure on the liquid reduces the temperature at which it vaporizes.

Since the *collection* of the heat is accomplished by providing a receptacle, or heat sink, at a temperature lower than that of the space to be refrigerated, we will maintain our receptacle at a relatively low pressure, allow our refrigerant to vaporize in it, and term it an "evaporator."

We will accomplish the *transportation* of the heat away from the receptacle by withdrawing the vaporized refrigerant from the receptacle, and since the refrigerant is normally too costly to throw away, provide some means of discarding the heat from it, recovering it as a liquid, and returning it to the evaporator in a closed cycle.

The four fundamental units needed in a closed cycle of refrigeration are (1) the evaporator to serve as our heat sink, (2) some device for withdrawing the vaporized refrigerant from the evaporator at a rate which will maintain the desired low pressure in the evaporator, and discharging it at a higher pressure so that its increased boiling point exceeds the temperature of the surroundings, (3) a con-

lowering the pressure on a liquid lowers the temperature at which it vaporizes; on a hunting trip in the mountains, water for your coffee boils at a lower temperature than it does in the valley below. Let's see how we apply these principles to our refrigeration process. [Uncover Chart I.]

Note the attempt to clarify an idea by means of comparison—the "water sink."

The collection of heat is accomplished by providing a receptacle at a temperature lower than that of the space to be refrigerated, so that heat tends to flow from the surrounding space to the lower temperature level of the receptacle. The receptacle is generally termed a "heat sink," just as a low-level ground area in a wet region is sometimes called a "water sink." We will fill *our* heat sink with liquid refrigerant, and then lower the pressure in the sink so that the refrigerant evaporates rapidly at a low temperature, absorbing heat from the surrounding space. This particular type of heat sink we call an "evaporator."

The original devoted one sentence to evaporation, one to transportation. This version devotes four to the former, three to the latter.

A speaker must cover important ideas carefully: he must not present them too fast. An audience lost at this point will be lost for good.

With the heat collected, we transport it away from the space by exhausting the gaseous refrigerant from the evaporator. This step might be very simple if we could discard the heat, refrigerant and all, to the atmosphere. But normally the refrigerant is too costly to waste, so economy dictates that we shall provide in the transportation step some means for discarding *only* the *heat*, while recovering the refrigerant as a liquid and returning it to the evaporator in a *closed cycle*. [Uncover Chart II.]

The transition here is strengthened by starting this paragraph with "Closed-Cycle." The sentences listing fundamental units have been shortened so that the ideas can be more readily grasped.

Closed-cycle refrigeration involves four fundamental units: First, the evaporator to serve as the heat sink. Second, some device for withdrawing vapors from the evaporator, then discharging them at an increased pressure and temperature level. Third, a condenser with which to extract the latent heat of the refrigerant and return it to the liquid state. And fourth, an expansion valve with which to reduce the pressure on the liquid refrigerant as it returns to the evaporator.

denser in which the heat is extracted from the refrigerant at its increased boiling point, returning it to the liquid state, and (4) an expansion valve to reduce the pressure of the liquid refrigerant as it is again passed into the evaporator.

Note how the emphasis is changed in expressing this in the final version. See top of page 391.

The second of these steps may be accomplished by a number of devices, but they may all be grouped under two general types of system, the "compression" system and the "absorption" system.

The compression system is the one more commonly used, employing a centrifugal or reciprocating compressor to withdraw the vaporized refrigerant, do work on it, and discharge it at an increased pressure.

The absorption system, however, is probably the more interesting, both from the engineering and the popular viewpoint.

References in these paragraphs are to illustrations not reproduced here.

Did you ever wonder how you can light a fire in the bottom of your refrigerator and take ice out the top? Well, it isn't quite as simple as it might appear from the way our befuddled friend here is making ice cubes to cool his glass of water.

The principles of the process were first discovered by the noted scientist Michael Faraday in 1823. Following Faraday's work, Ferdinand Carré, a Frenchman, developed a simple intermittent refrigeration system, and then, in 1850, patented the first practical continuous refrigeration machine.

As in Carré's machine the modern continuous ammonia absorption machine operates as follows. Liquid ammonia from the condenser is passed through an expansion valve into the evaporator, where the ammonia vaporizes. In these steps the process is exactly like the compression system. However, the gaseous ammonia leaving the evaporator, instead of being passed through a compressor, is absorbed in water. The resulting solution of ammonia in water is pumped to a tank called the generator, maintained at the higher

The subject of the parallel paragraph in the original was "The second of these steps." The change to "The device" allows a more sensible and natural lead into a discussion of the two systems.

The device used in the second of these steps may take a number of forms, but these forms may be classified under the two general types of refrigeration systems—the "compression system" and the "absorption system."

The *compression system* is the commoner of the two, employing a centrifugal or reciprocating compressor to take in the vaporized refrigerant, do work on it, and then discharge it at a high pressure and temperature.

The *absorption system*, however, is the more complicated and the more interesting, both from the engineering and from the popular viewpoint.

Do you, perhaps, have in your home the type of refrigerator in which you light a fire in the bottom and take ice cubes out the top? [Uncover Chart III.]

It seems a bit paradoxical, doesn't it? Our friend here, though, an engineer relaxing from a hard day at the office, understands the system perfectly. He's in a hurry for ice cubes, so he's giving the refrigerator a boost.

To make sure his audience is with him, he begins with a reminder that this is the absorption type. Compare with the original.

Mention of Carré's intermittent system is omitted here as unnecessary. See earlier version.

This is the *absorption* type of refrigerator. The principles of this system were discovered by the noted scientist Michael Faraday, in 1823, during his work on the liquefaction of gases. A Frenchman, Ferdinand Carré, patented, in 1860, the first practical continuous absorption refrigerating machine. [Uncover Chart IV.]

Carré's machine uses ammonia as the refrigerant. High-pressure liquid ammonia from the condenser is passed through an expansion valve into the evaporator, where it vaporizes, absorbing heat. In these two steps the Carré machine is identical with the compression machine. The vapors from the evaporator, however, instead of being picked up by the suction side of a compressor, are absorbed into water. The resulting solution of ammonia in water is transferred by a suction pump to a tank called the "generator," main-

pressure of the condenser. Heat is applied to the generator, driving the ammonia out of solution. The water is returned to the absorber, and the gaseous ammonia to the condenser, from where the cycle is repeated.

This and the next four paragraphs explain the contribution of Platen and Munters.

But in 1926 there occurred a modification of Carré's machine which resulted in the most revolutionary development to occur in absorption refrigeration. It was conceived by two young undergraduate students at the Royal Institute of Technology in Stockholm, Baltzar von Platen and Carl Munters.

These students proposed to convert the Carré machine into a constant-pressure apparatus by introducing hydrogen into the evaporator and absorber to equalize the pressure with that in the generator and condenser. This might seem offhand to nullify the principle of a machine which produces refrigeration by the evaporation of a liquid at a reduced pressure. However, the hydrogen molecules in the evaporator, unlike the gaseous ammonia molecules, exert no effect whatever tending to keep the remaining ammonia molecules in the liquid state. Hence, passing liquid ammonia from an atmosphere of gaseous ammonia to one of mixed hydrogen molecules and gaseous ammonia molecules reduces the *effective* pressure on the ammonia just as surely as if it had been passed through an expansion valve.

Then there is no need for the expansion valve.

Since the total pressure in the absorber is the same as that in the generator, there is no need for the pump that formerly served to transfer the solution from the low-pressure to the high-pressure side of the machine—the transfer may be accomplished by gravity flow.

There is no longer a higher pressure in the generator to force the water back to the absorber, so we will replace the valve with a simple vapor lift, similar to that used in the coffee percolator.

tained at the same high pressure as the condenser. A flame is applied to the generator, bringing the solution to a boil. The ammonia gas boils through a pressure-reducing valve, and the gaseous ammonia continues to the condenser for liquefaction.

Only minor changes here —somewhat more detailed for clarity.

In 1926 there occurred a modification of the Carré machine which resulted in the most revolutionary development in absorption refrigeration to date. Two young Swedish students at the Royal Institute of Technology in Stockholm, Baltzar von Platen and Carl Munters, conceived an invention to eliminate the valves and the pump from the Carré machine. This they proposed to do by the simple expedient of adding hydrogen to the "low-pressure side" of the system, thus converting the Carré machine into a *constant-pressure apparatus*.

In this version the material in this and the next four paragraphs is differently organized to make it clearer and more interesting. Note the use of more pronouns.

Now here is a refrigerating machine which operates on the principle of vaporizing a refrigerant under *low* pressure, then condensing it under high pressure. It might appear that, on *equalizing* the pressure throughout the apparatus, we have immediately nullified the principle of operation.

The secret lies in the use of *hydrogen*, explained as follows: It is the *gaseous* ammonia in the atmosphere of the evaporator which exerts a pressure on the *liquid* ammonia, making it difficult for the liquid to vaporize. (It was for this reason that Carré reduced as much as possible the pressure in the evaporator.) The *hydrogen* molecules *exert no such effect* on the liquid ammonia. And so, on adding hydrogen to the atmosphere of the evaporator, we have reduced the *effective pressure* on the ammonia just as surely as if we had reduced the *total* pressure in the evaporator. Furthermore, by maintaining the total evaporator pressure the same as the condenser pressure, we have eliminated the need for the expansion valve.

With the hydrogen also present in the absorber, the pressure in the absorber is the

The importance of the Platen-Munters features is emphasized by the fact that an American corporation paid five million dollars for the patent rights.

In this and the next four paragraphs Galt explains the operation of a highly developed machine in which the Platen-Munters features are incorporated. Note that the style is spare and economical.

This corporation has since marketed a highly developed form of the Platen-Munters machine, unique in its valveless, pumpless control of fluids within a hermetically sealed space. It contains three interrelated fluid circuits, rotating in unison to produce continuous refrigeration, powered by nothing more than a small source of heat. These three circuits consist of an ammonia loop, an ammonia-hydrogen loop, and an ammonia-water loop.

The process is shown diagrammatically and much simplified in Fig. V. Beginning with the ammonia-hydrogen loop, the ammonia enters the evaporator through a liquid trap which confines the hydrogen to its own circuit. In the evaporator it vaporizes, producing refrigeration. The heavier gaseous ammonia molecules mix with the hydrogen molecules, and the resulting increase in the density of the mixture causes the heavy gas to sink down the vertical tube to the absorber.

In the absorber, the ammonia dissolves in the countercurrent stream of water, while the practically insoluble hydrogen, lightened of its burden of heavy ammonia molecules, ascends to the evaporator to again perform its task of mixing with and reducing the partial pressure of the ammonia.

Taking up the water-ammonia loop, the strong solution of ammonia in water, called "strong aqua," flows by gravity to the generator, where the application of heat drives the ammonia out of solution. A vertical tube, the inside diameter of which is equal to that of the bubbles of gas formed, projects below the surface of the boiling liquid, so that as the gas bubbles ascend the tube they carry with them slugs of liquid. This "liquid lift" empties into the separator, where the ammonia vapor is separated from the "weak aqua."

same as that in the generator, and there is no need for a pump to transfer the solution of ammonia in water—the transfer can be done by gravity flow. The pump is eliminated.

This paragraph is new.

We no longer have higher pressure in the generator to transfer water to the absorber through the pressure-reducing valve, but we *do* have in the generator a boiling liquid. So we substitute for the pressure-reducing valve a simple "vapor lift," like that used in your coffee percolator.

No valves, no motor, no pump. The only external source of energy, a direct flame on the generator. *Ice*—from *heat!* It's amazing, isn't it?

The importance of the Platen-Munters features is emphasized by the fact that an American corporation paid *five million dollars* for their United States patent rights!

Since that time this corporation has marketed a highly developed form of the Platen-Munters machine, unique in its valveless, pumpless control of fluids within a hermetically sealed space.

Note the personal element in this paragraph—which is not in the other version.

If you own a gas refrigerator, you may be interested in seeing how it works. [Uncover Chart V.]

In five paragraphs, beginning here, the action of a modern gas refrigerator is explained (by reference to a chart) as before, but this version is clearer, more direct and concrete, and personal.

We'll pick up the flow at the generator, where our engineer friend applied his blowtorch. In the generator there is a solution of ammonia in water. The application of heat causes the solution to boil, releasing gaseous ammonia. The ammonia bubbles ascend the vertical tube to the separator, carrying with them slugs of water, which empty into the separator and flow to the absorber. The ammonia continues to the condenser, where it is liquefied.

Liquid ammonia flows from the condenser to the evaporator, where, in an atmosphere of hydrogen, it evaporates rapidly at a low temperature, absorbing heat from the water in the surrounding ice trays and producing ice.

The heavy molecules of gaseous am-

The weak aqua then returns to the absorber by gravity through a second liquid seal.

Finally, the ammonia loop, which has been traced as far as the separator, next involves the "condenser," which removes the latent heat from the vapor, converting it into cool liquid ammonia. From here it passes through the liquid seal that marks its re-entry into the evaporator, and the cycle has been completed.

The industrial modifications of this machine are many and interesting, but we have traced the evolution of the artificial ice-making machine far enough to appreciate the resourcefulness that made it possible.

The frontiers of science are unlimited; the engineer thrives on the meat of research and development; it is not frequent that he can point to a feat of reduction of the price of a commodity to one one-thousandth of 1 per cent of its onetime cost, but as long as there is an unsolved problem in man's advancement, there will be an engineer.

Galt closes with a reference to the cost of ice, which served as a point in his lead.

monia, mixing with the lighter molecules of hydrogen, increase the density of the mixture, causing it to sink down the tube to the absorber.

In the absorber, the gaseous stream meets a countercurrent stream of water from the separator. The ammonia dissolves in the water, but the practically insoluble hydrogen, now relieved of its load of ammonia molecules, ascends again to the evaporator.

In this last paragraph of the body of the talk, cost—sure to be of interest to all listeners—is mentioned.

The solution of ammonia in water flows by gravity from the absorber to the generator. The cycle is complete. The motivating power, a tiny flame. The cost to you, some fifty cents a week.

In these closing paragraphs, a more effective conclusion is given by omitting mention of other facts that might be discussed but cannot be, and by reverting more specifically to the cost factor which has been his "dramatic" lead item. There's more dash to this conclusion than to the former.

Altogether, there are two observations to be made in conclusion: (1) the final version is clearer and simpler, and (2) it is more personal and therefore more likely to attract attention and interest.

These have been some specific facts in the story of artificial refrigeration—the story of the successful development of a process for the industrial marketing of ice at about *six dollars a ton*, less than *one one-thousandth of 1 per cent* of its onetime cost. It is a process characterized by convenience and economy, the fruits of engineering research in the science of refrigeration.

The next time you open your refrigerator door for a glass of ice cubes, recall a picture of armies of slaves returning from mountainous regions with snow to cool the wine of medieval kings.

Remember that the people of New Orleans once *gladly* paid *five hundred dollars a pound* for ice!

One of the First Drafts of the Galt Report

Cold Facts

One of the chemical engineer's primary concerns is with economic problems. Hence it is of interest to him when he reads of a process whereby the cost of a common commodity has been reduced from 500 dollars per pound to half a cent per pound.

Although similar to the lead in version two, this one is less lively and is somewhat stilted. Here we are bluntly told that the subject is of interest. No mention of the subject—artificial ice-making—is made here. Compare with the second version where he sensibly announces his subject at the outset.

Until the nineteenth century, the summer supply of ice to the southern part of the United States consisted of cartloads, cut from the northern lakes and ponds during the winter, packed in sawdust and canvas, and conveyed laboriously southward. During the yellow-fever epidemic of the early 1800's in New Orleans, this ice sold for as high as $500 per pound to relieve the suffering of fever-ridden patients.

Here he explains the startling statement which ends the first paragraph. Compare with the expanded version.

The Final Draft of the Galt Report

Cold Facts

THE STORY OF ARTIFICIAL REFRIGERATION

Summary

For this final version, Mr. Galt has added a summary. In the light of what this text has to say on the subject of summaries and abstracts, what do you think of this one?

The following pages present a story exemplifying the engineering resourcefulness of man in his never-ending struggle for independence from nature.

Thousands of years ago man found reasonably satisfactory methods of keeping himself and his dwelling warm, but until comparatively recently, few means had been developed, other than simple ventilation, for his protection against heat.

Dr. William Cullen, a Scottish physician of the eighteenth century, is credited with invention of the first artificial refrigeration machine, and the passage of time since that date has been marked by the steady increase in the efficiency, and decrease in the cost, of man's efforts to control the cooling of his habitat. Modern ice-making machines are miracles of ingenuity—monuments to the progress of humanity.

I. Introduction

Since his readers are not all chemical engineers, he has dropped the adjective here. Galt makes the lead here more dramatic by changing the terms of the cost comparison from pounds to tons. The longer sentences of this version give a smoother style.

One of the engineer's primary concerns, in his never-ending development of processes and products for the advancement of mankind, is with economic problems. Occasionally there occurs, through the medium of engineering development, a cost reduction which is nothing short of phenomenal. History reveals just such a feat in the evolution of the modern industry of artificial ice making, a process that has succeeded in reducing the onetime cost of that commonest of commodities from a *million dollars a ton* to its present cost of less than *six dollars a ton.*

The chief difference between this second paragraph and that in the earlier draft is in the addition of details. These added concrete details help the reader understand the situation referred to in the opening paragraph and they add interest. The admission that ice was normally a luxury item in the South would forestall the pos-

Until the nineteenth century, the summer supply of ice to the southern part of the United States came from the North, ice that had been cut from frozen lakes and ponds during the winter, stored in sawdust and canvas, and conveyed laboriously southward later in the year. There were no railroads south of the Mason-Dixon Line, so transportation was accomplished by river barges and by oxcarts. Ice, needless to say, was a luxury item in the South, and brought a high price even under normal circumstances. But during the New

The style here is rougher than in the revision. Still no mention of refrigeration engineering, his subject!

The history of artificial ice making began in 1755 at the University of Glasgow, where Dr. William Cullen produced ice with an experimental vacuum machine. The first American machine was built by Dr. John Gorrie of Apalachicola, Florida, also a physician, in 1844, and development of the process proceeded rapidly in the United States thereafter.

Refrigeration is a process whereby heat is transferred from a place where it is undesirable to one where it is unobjectionable. In order to do so, the heat must first be collected, then transported away from the cooled space.

The collection of the heat is accomplished by providing a receptacle which is at a temperature lower than that of the cooled space. This receptacle is termed a "sink."

What do you think of the phrase "the discard

The transportation of heat from the sink and the discard thereof depends on the

sible objection from some readers that the figures given above were misleading.

The addition of the phrase, "man's answer . . . ," helps make the transition from the lead into this historical part of his introduction. What do you think of his use of the word "habitat"? The ending of this paragraph has been changed to get in a reference to refrigeration engineering. Note also how the statement varies in fact from that in the preceding version.

The centered heading is a transitional device. Note how the emphasis is strengthened by changing the structure of the second sentence and how this sentence now forecasts the topic sentences of the two following paragraphs.

Orleans yellow-fever epidemic of 1853, ice sold for the fantastic price of *five hundred dollars per pound* to relieve the suffering of fever-ridden patients.

The history of artificial ice making, man's answer to the need for controlled cooling of his habitat, had begun in 1755 at the University of Glasgow, where Dr. William Cullen produced ice with an experimental vacuum machine. The first American machine was built in 1844 by Dr. John Gorrie of Apalachicola, Florida, also a physician, but it was a number of years before the work of these and other pioneers blossomed into the modern science known as "refrigeration engineering."

II. Definition of Refrigeration

"Refrigeration" is a process whereby heat is transferred from a place where it is undesirable to a place where it is unobjectionable. The process involves two problems, the *collection* of the heat, and its *transportation* away from the cooled space.

The collection of heat is accomplished by providing a receptacle which is at a tem-

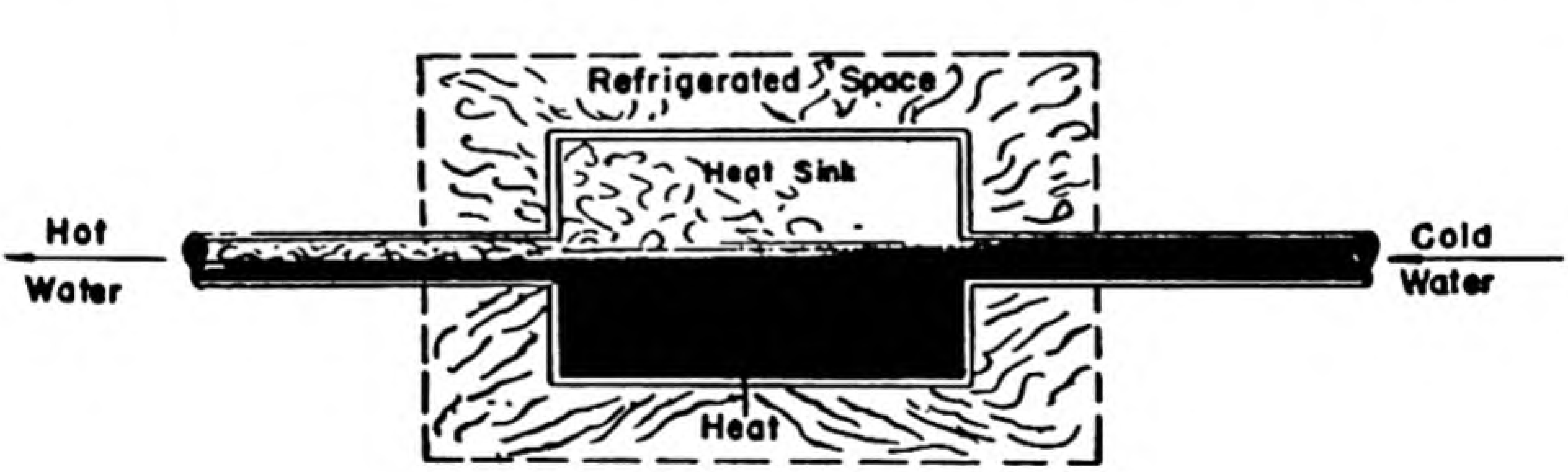

FIG. I

perature lower than that of the space to be cooled. This receptacle is termed a "heat sink."

The transportation of heat from the sink and the discard thereof depend on the

thereof" in both versions?

method of collection. If an ample supply of a naturally cooled material, such as cold water, is available and applicable to the problem, the transportation of the heat is accomplished by the flow of the water to, through, and from the receptacle, after which the heated water may be discarded. More generally, a "vapor compression" system is used, in which case the discard device consists of a mechanical means for raising the temperature level of the heat collected at the sink to a value greater than that of the surroundings, so the heat may be dissipated to the air or to some other convenient cooling system.

Note how this material is handled in the final draft.

When a volatile liquid is used as the working substance, or "refrigerant," the heat sink is termed the "evaporator." When, as is usually the case, the refrigerant does not boil at a temperature less than that of the cooled space, nor is it replaceable at a low cost, economy dictates the need for inclusion of equipment which makes possible the reclaiming of the vapors and the re-use thereof in a closed cycle.

method of collection. If an ample supply of a naturally cooled material, such as cold water, is available and applicable to the problem, the transportation of the heat is accomplished by the flow of the water to, through, and from the receptacle, after which the heated water may be discarded (Fig. I). More generally, however, the "vaporization refrigeration" method is used, in which case the transportation, as well as the collection, of the heat becomes a more complicated process.

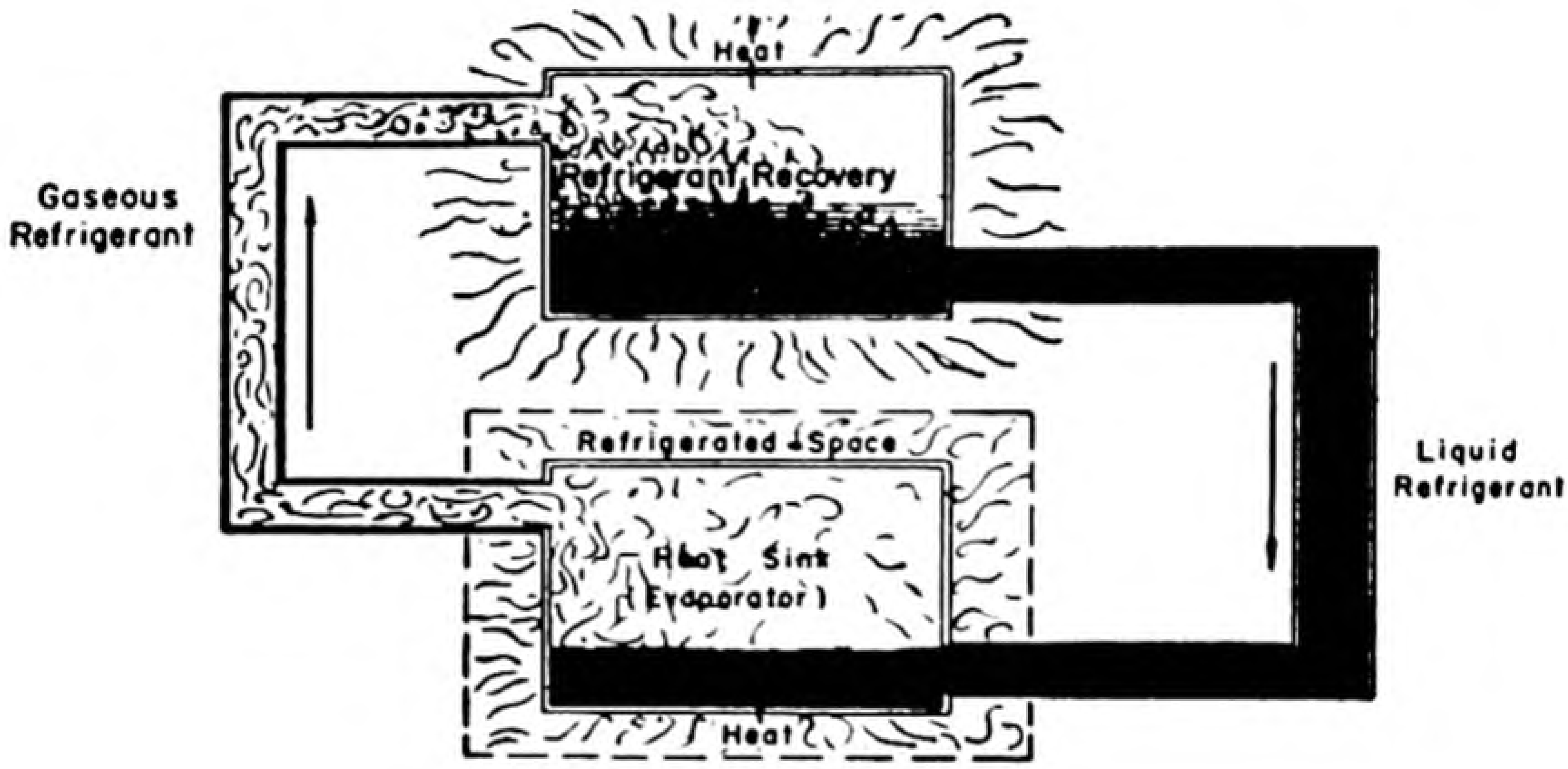

FIG. II

Note how he has proceeded more cautiously in this version, giving principles before the details of the operation. Is this version clearer?

Vaporization refrigeration is based on two fundamental principles: (1) Liquids, on volatilization, absorb relatively large quantities of heat with no increase in the temperature of the fluid. (2) Lowering the pressure on the liquid lowers the temperature at which it vaporizes.

Using, then, as a refrigerant, a volatile liquid, the heat sink is maintained at a low pressure and is termed an "evaporator." Since the refrigerant is not usually replaceable at a low cost, economy dictates the need for inclusion, in the "transportation" step, facilities which make it possible to discard the heat to the atmosphere while reclaiming the vapors and re-using them in a closed cycle (Fig. II).

The discussion of fundamental units is the same in both versions.

The four fundamental units which are needed in a closed system of mechanical refrigeration are: (1) the evaporator to serve as the heat sink; (2) a device for removing vapor from the evaporator to maintain the operating pressure, and then to discharge the vapor at a higher pressure so that its increased boiling point exceeds the temperature of the surroundings to which its heat is to be discarded; (3) a condenser where the vapor gives up its sensible and latent heat and again becomes a liquid; and (4) an expansion valve to reduce the pressure of the refrigerant to that of the evaporator.

There are no figures in this version.

The device necessary to the accomplishment of the second step in this cycle may take a number of forms. The two most common ones are those shown in Fig. I, the "compression system" and the "absorption system."

III. Units Required for Closed-Cycle Refrigeration

The four fundamental units which are needed in closed-cycle mechanical refrigeration are: (1) the evaporator to serve as the heat sink; (2) a device for removing vapor from the evaporator at a rate which will maintain the desired operating pressure therein, then discharging the vapor at a higher pressure so that its increased boiling

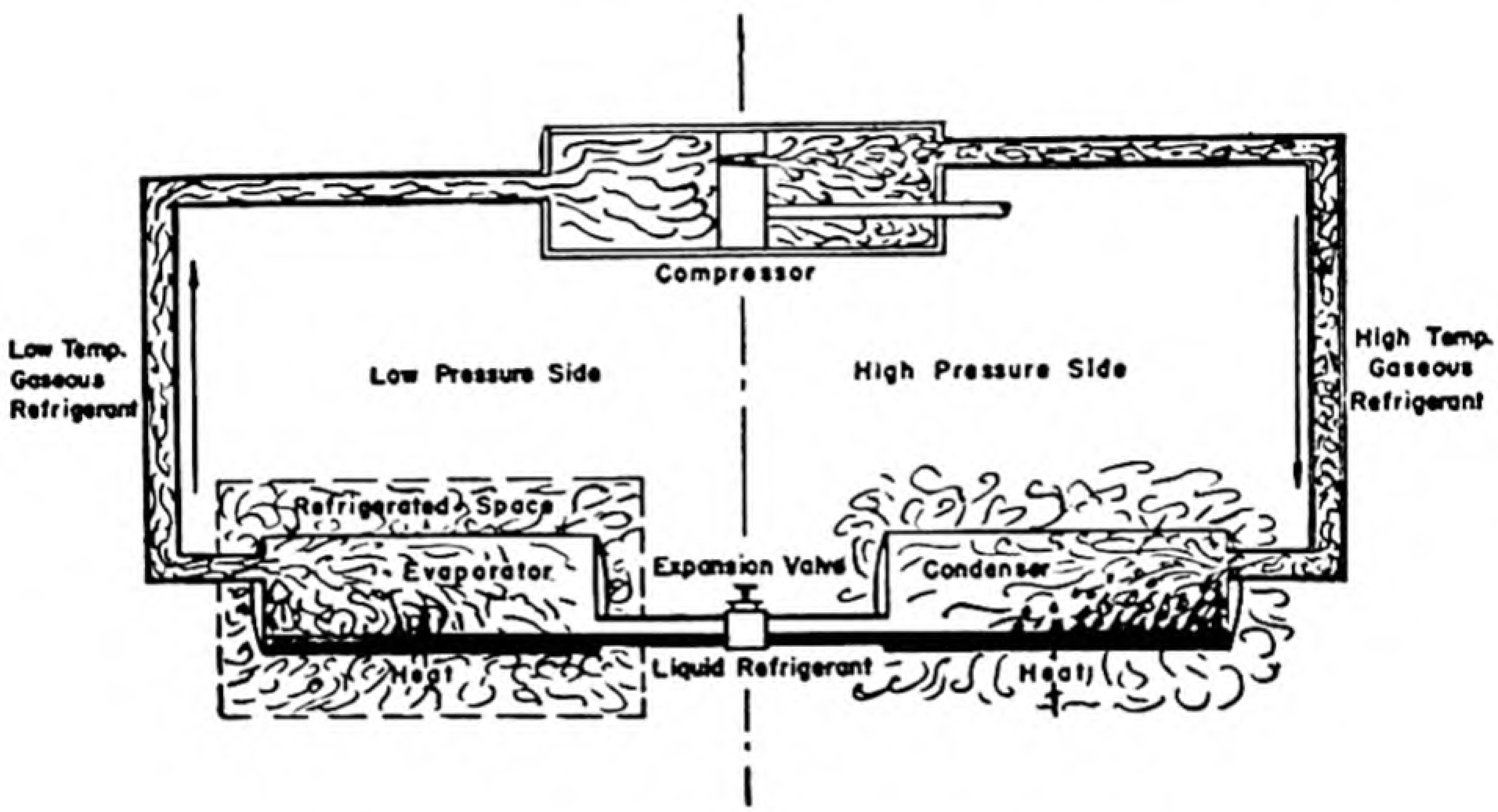

FIG. III

point exceeds the temperature of the surroundings to which its heat is to be discarded; (3) a condenser where the vapor may give up its latent heat and again become a liquid, and (4) an expansion valve to reduce the pressure of the liquid refrigerant as it returns to the evaporator (Fig. III).

IV. Types of Refrigeration Systems

The device necessary to the accomplishment of the second step in this cycle may take a number of forms. These forms may be grouped under two general systems of refrigeration, the "compression system" and the "absorption system."

The compression system is the one most commonly used, consisting merely of a reciprocating or centrifugal compressor which takes in low-pressure vapor, does work on it, and discharges it at a higher pressure.

The discussion of Faraday remains about the same in both versions. One of Mr. Galt's readers suggested that this discussion of Faraday's work needed clarifying. See figure in the final draft. The sentence beginning "He condensed . . ." is split into two statements.

The absorption system, however, is the most interesting of the two, using as a working substance a solution of two or more materials. The principles of the process were first demonstrated, unknowingly, by the noted chemist Michael Faraday in 1823. Faraday discovered that silver chloride would absorb ammonia, and, on heating the mixture in one end of a bent glass tube, the ammonia would be evolved. He condensed the gas in the other end of the tube by immersing it in an ice-salt mixture, and found that on removing the tube from the bath, the ammonia boiled, producing a temperature far lower than that of the ice-salt bath with which it had been condensed. Faraday had actually operated the first simple intermittent absorption system, using silver chloride as the absorbent and ammonia as the refrigerant.

Note the use of subheadings for emphasis.
The word "merely" in the first sentence of this paragraph in the first version has been deleted. What attitude did the term suggest in the earlier draft?

A. Compression Refrigeration

The compression system, illustrated in Fig. III, is the one most commonly used, employing a reciprocating or centrifugal compressor which takes in low-pressure vapor, does work on it, and discharges it at a higher pressure.

B. Absorption Refrigeration

The absorption system, however, is the more interesting of the two, using as a working substance a solution of two or more materials.

Why do you suppose he changed "chemist" to "scientist" in this version (in describing Faraday)?

The suggestion (from a reader of the early draft)

Faraday's Work. The principles of the process were first demonstrated, unknowingly, by the noted scientist Michael Faraday in 1823. Faraday discovered that silver chloride would absorb ammonia; on heating the mixture in one end of a bent glass tube (Fig. IV), he caused the ammonia to be evolved.

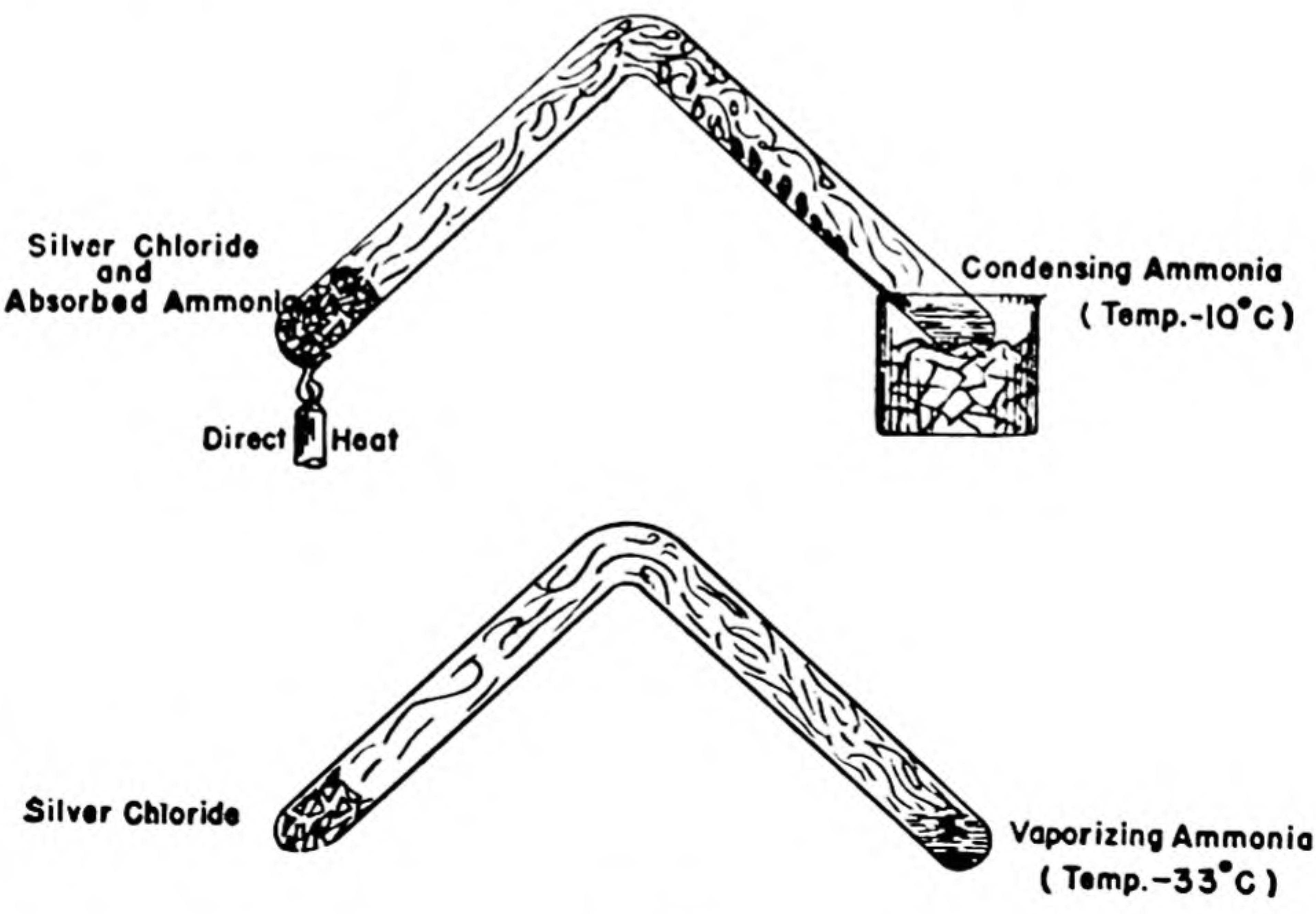

FIG. IV

No change in the discussion of the Crosley Icy Ball.

The modern counterpart of Faraday's system is the Crosley Icy Ball, with its two balls connected by a length of pipe. In its simplest form, the first ball, containing a strong solution of ammonia in water, is heated, with the second ball being cooled by water. After ammonia has been boiled out of the solution in ball No. 1 and condensed in ball No. 2, ball 1 is removed from the heat source and cooled. Refrigeration is then produced by ball 2, as the ammonia vaporizes and is reabsorbed in the weak solution in ball 1.

Following the work of Faraday, Ferdinand Carré developed the first practical continuous refrigerating machine in France in

that greater clarity was needed was met by the figure. Do you think the figure clarifies the discussion?

He condensed the gas in the other end of the tube by immersing it in an ice-salt mixture, and found that, on removing the tube from the bath, the ammonia boiled. The important aspect of the experiment was that the vaporization of the ammonia produced a temperature far lower than that of the cold bath with which it had been previously condensed.

Lest it be overlooked, Galt calls attention to the important significance of Faraday's experiment in this separate sentence.

Faraday had actually operated the first simple intermittent absorption system, using silver chloride as the absorbent and ammonia as the refrigerant.

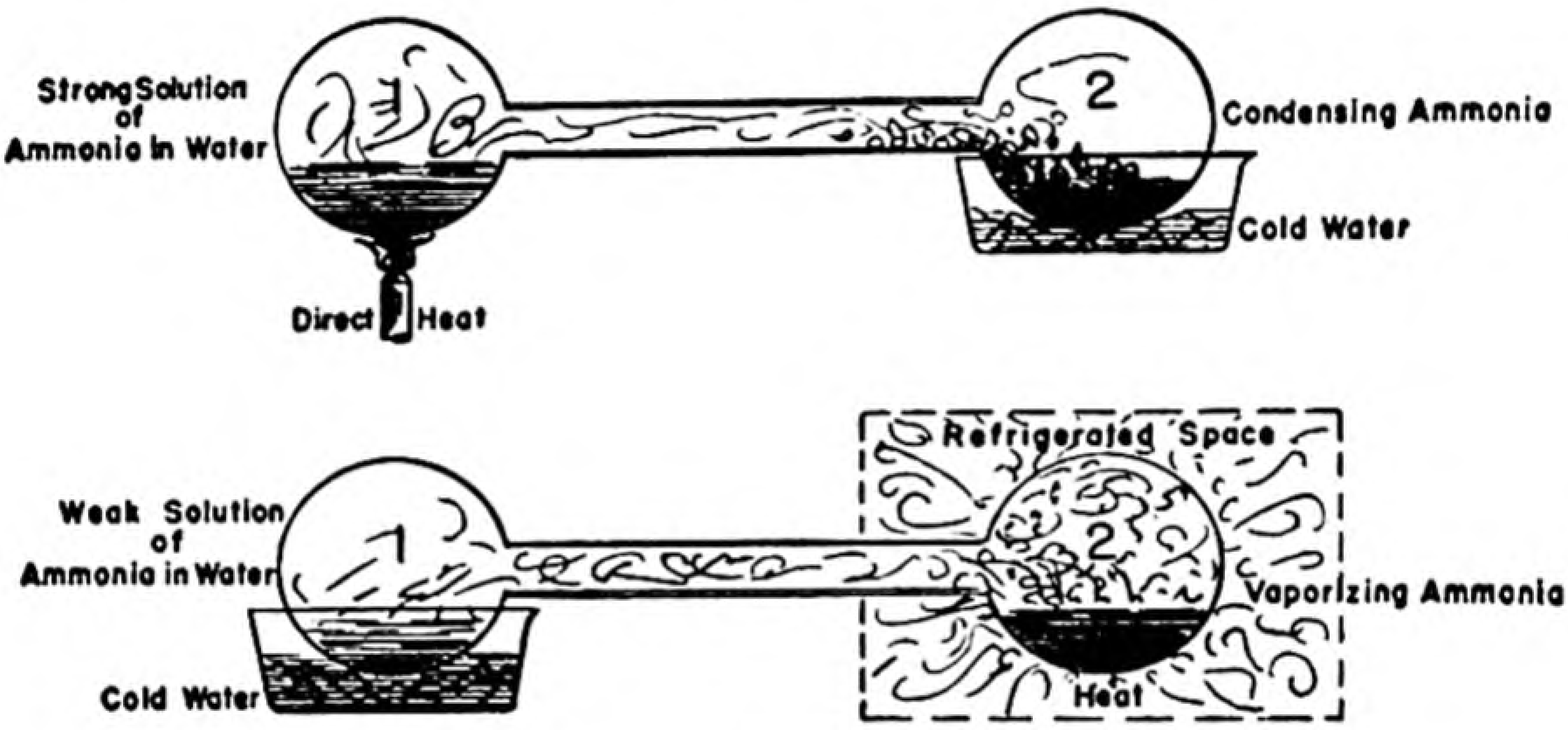

FIG. V

Crosley Icy Ball. The modern counterpart of Faraday's system is the Crosley Icy Ball, with its two balls connected by a length of pipe (Fig. V). In its simplest form, the first ball, containing a strong solution of ammonia in water, is heated, the second ball being cooled by water. After ammonia has been boiled out of the solution in ball No. 1 and condensed in ball No. 2, ball 1 is removed from the heat source and cooled. Refrigeration is then produced by ball 2, as the ammonia vaporizes and is reabsorbed in the weak solution in ball 1.

This discussion of Carré remains about the same as that in the earlier version. He does add the

The Carré Machine. Following the work of Faraday, Ferdinand Carré developed and patented the first practical continuous re-

Note the difference in dates in the two versions.

1850. Carré's basic idea was to use the affinity of water for ammonia by absorbing in it the gas from the evaporator, then using a suction pump to transfer the liquid to another vessel where the application of heat caused the liberation of ammonia gas at a higher pressure.

The sentence beginning "As in Carré's machine . . ." does not make it clear whether the Carré machine is exactly the same as the ammonia absorption system or not.

As in Carré's machine, the simple continuous ammonia absorption machine consists of four units: the evaporator, the absorber, the generator, and the condenser. In the ammonia-water system, high-pressure liquid ammonia from the condenser is allowed to expand through an expansion valve and the low-pressure liquid is then vaporized in the evaporator, absorbing its latent heat of vaporization from the surrounding refrigerated space. In these two steps the ammonia absorption system is exactly like the compression system. However, the gas from the evaporator, instead of being passed through a compressor, is absorbed in a weak solution of ammonia in water. The resulting strong solution is then pumped to the generator, which is maintained at high pressure. Here the strong solution is heated and the ammonia gas driven off. The weak solution which results flows back to the absorber, the highly compressed ammonia gas from the generator is condensed, and the cycle repeated.

fact that Carré patented his machine, and clears up a small matter of pronominal reference in the second sentence.

frigerating machine in France in 1860. Carré's idea was to use the affinity of water for ammonia by absorbing in water the gas from the evaporator, then using a suction pump to transfer the liquid to another vessel where the application of heat caused the liberation of ammonia gas at a higher pressure and temperature.

He leaves out the sentence in which he listed the four components of the system. Do you think he should have?

Carré's machine is illustrated by the flow diagram in Fig. VI. In this ammonia-water system, high-pressure liquid ammonia from the condenser is allowed to expand through an expansion valve and the low-pressure liquid is then vaporized in the evaporator, absorbing its latent heat of vaporization from the surrounding refrigerated space. In these two steps the ammonia absorption system is exactly like the compression system. However, the gas from the evaporator, instead of being passed through a compressor, is absorbed in a weak solution of ammonia in water ("weak aqua"). The resulting strong solution ("strong aqua") is then pumped to the generator, which is maintained at high pres-

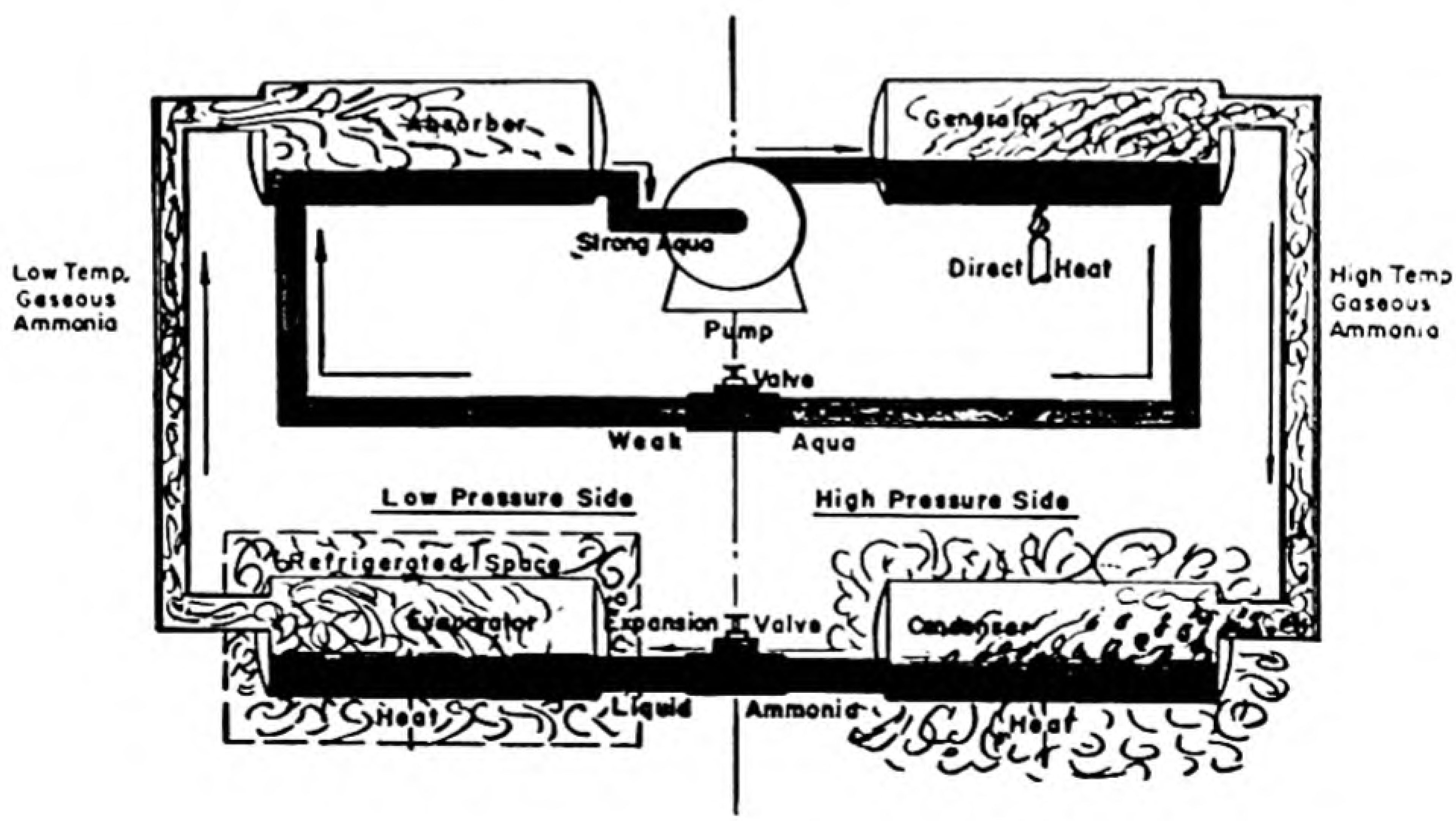

FIG. VI

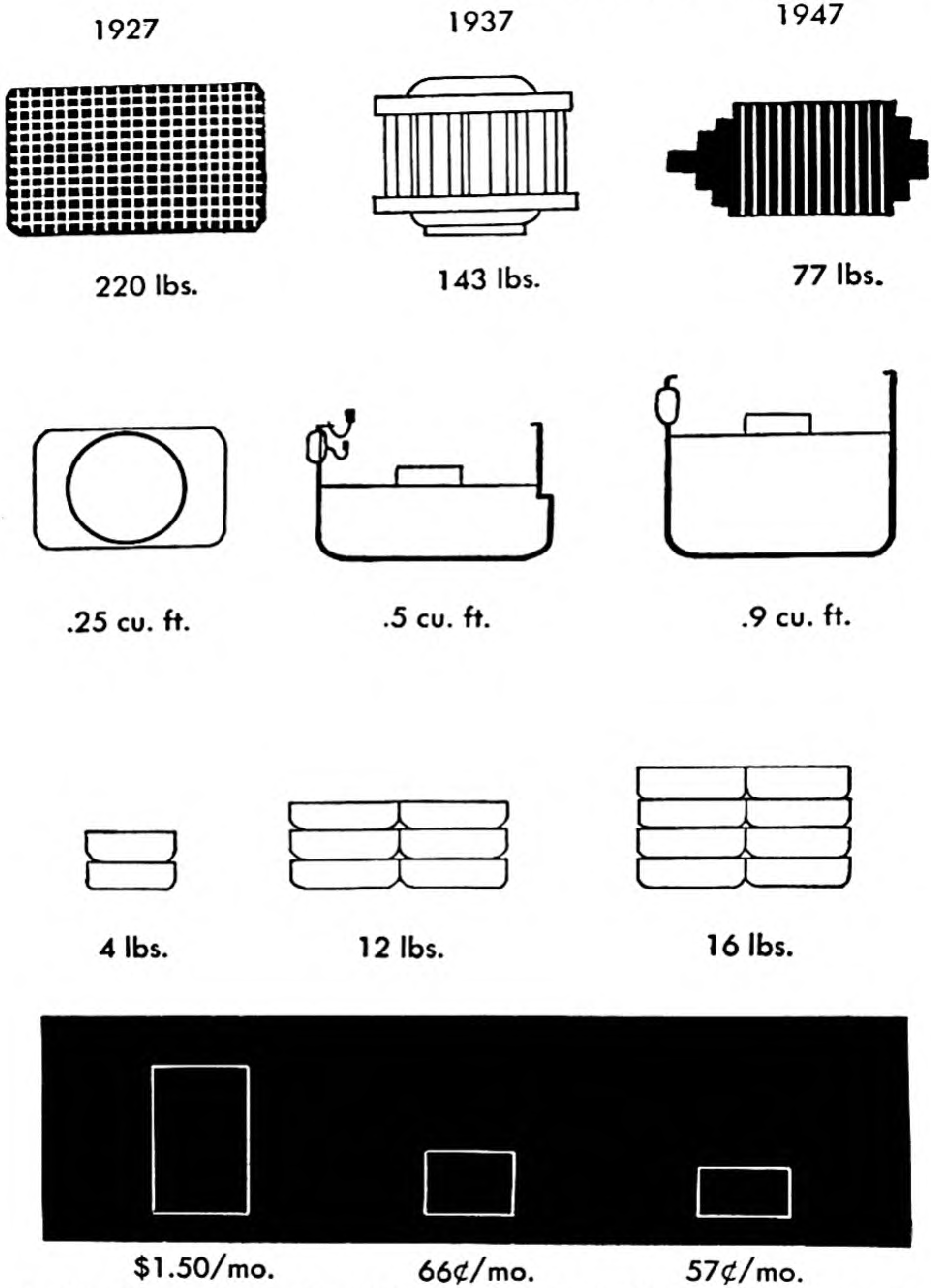

FIG. VII. Development of the General Electric Refrigerator. *Top line:* Decreasing weight of the refrigerating mechanism; *second line:* increasing volume of the freezing space; *third line:* increasing ice capacity; *bottom line:* decreasing cost of operation. Redrawn from the original photograph.

This transition sentence (to the reference to Geppart) is not very effective—not very clear, in fact.

Small ammonia absorption units have played an important part in the development of the absorption system. In 1900 Geppart proposed to convert the water-ammonia absorption machine into a constant-pressure device by adding some permanent gas to the system. His plan was to circulate the gas over the liquid ammonia in the evaporator, causing accelerated evaporation.

This introductory paragraph about Platen and Munters stands in the final version.

But nearly twenty-five years later occurred the modification of Geppart's idea which resulted in the most revolutionary development yet to occur in absorption refrigeration. It was an invention to eliminate all valves and pumps in the Carré machine, conceived by two undergraduate students at the Royal Institute of Technology in Sweden, Baltzar von Platen and Carl Munters.

This paragraph remains unchanged in revision, except for a change of pronouns in the next to last sentence, and the omission of the last clause.

Its basis is Dalton's fundamental "law of additive pressures," which states that the total pressure of a gas mixture is the sum of the partial pressures of the individual components. The principle is applied by supplying an atmosphere of hydrogen in the "low-pressure" side of the apparatus, thus equalizing the pressure throughout the system. The desired drop in effective pressure on the ammonia as it leaves the condenser and enters the evaporator is accomplished by the change from an atmosphere of gaseous ammonia to one of a mixture of ammonia and hydrogen. The hydrogen molecules exert no effect tending to keep the ammonia molecules in the liquid phase; the concentration of ammonia molecules in the vapor phase is lessened by the presence of the hydrogen, and hence its pressure on the liquid ammonia is lessened. The result is that produced by the expansion valve in the Carré system—the ammonia evaporates

sure. Here the strong aqua is heated and the ammonia gas driven off. The weak aqua which results flows back to the absorber through a pressure-reducing valve, the highly compressed ammonia gas from the generator is condensed, and the cycle repeated.

The phrase "through a pressure-reducing valve" has been added for the sake of greater completeness and accuracy.

Geppart's Modification. In 1900 Geppart proposed to convert the water-ammonia absorption machine into a constant-pressure device by adding some permanent gas to the system. His plan was to circulate the gas over the liquid ammonia in the evaporator, causing accelerated evaporation.

This version omits the ambiguous opening sentence of the earlier version and proceeds at once to Geppart.

Platen-Munters Invention. But nearly twenty-five years later occurred the modification of Geppart's idea which resulted in the most revolutionary development yet to occur in absorption refrigeration. It was an invention to eliminate the pump and valves from the Carré machine, conceived by two undergraduate students at the Royal Institute of Technology in Sweden, Baltzar von Platen and Carl Munters.

The basis of this modification is Dalton's "law of additive pressures," which states that the total pressure of a gas mixture is the sum of the partial pressures of the individual components. The principle is applied by supplying an atmosphere of hydrogen in the "low-pressure" side of the apparatus, thus equalizing the pressure throughout the system. The desired drop in effective pressure on the ammonia as it leaves the condenser and enters the evaporator is accomplished by the change from an atmosphere of gaseous ammonia to one of a mixture of ammonia and hydrogen. The hydrogen molecules exert no effect tending to keep the ammonia molecules in the liquid phase; the concentration of ammonia molecules in the vapor phase is lessened by the presence of the hydrogen, and hence their pressure on the liquid ammonia is lessened. The result is that produced by the expansion valve in the Carré system—the

Is anything gained—or

rapidly at a relatively lower temperature and pressure, and the refrigerated space is cooled.

One of Mr. Galt's readers remarked that this portion of his discussion was not clear. Note the addition of a summary type of paragraph, as well as Fig. VIII, in the final draft.

Since, under these conditions, the total pressure in the absorber is also the same as that in the generator, there is no need for a pump to convey the strong solution from the absorber to the generator—the transfer can be accomplished by gravity flow. The return of weak solution to the absorber can no longer be done by the higher pressure in the generator, so a simple vapor lift, similar to that in a coffee percolator, is utilized.

The importance of the Platen-Munters features is emphasized by the fact that an American corporation paid five million dollars for their U.S. patent rights.

Since that time, a highly improved form of their machine has been developed, a machine unique in its valveless, pumpless control of fluids within a hermetically sealed

lost—by omitting the last clause of this paragraph?

ammonia evaporates rapidly at a relatively lower temperature.

Since, under these conditions, the total pressure in the absorber is also the same as that in the generator, there is no need for a pump to convey the strong aqua from the absorber to the generator—the transfer can be accomplished by gravity flow. The return of weak aqua to the absorber can no longer be

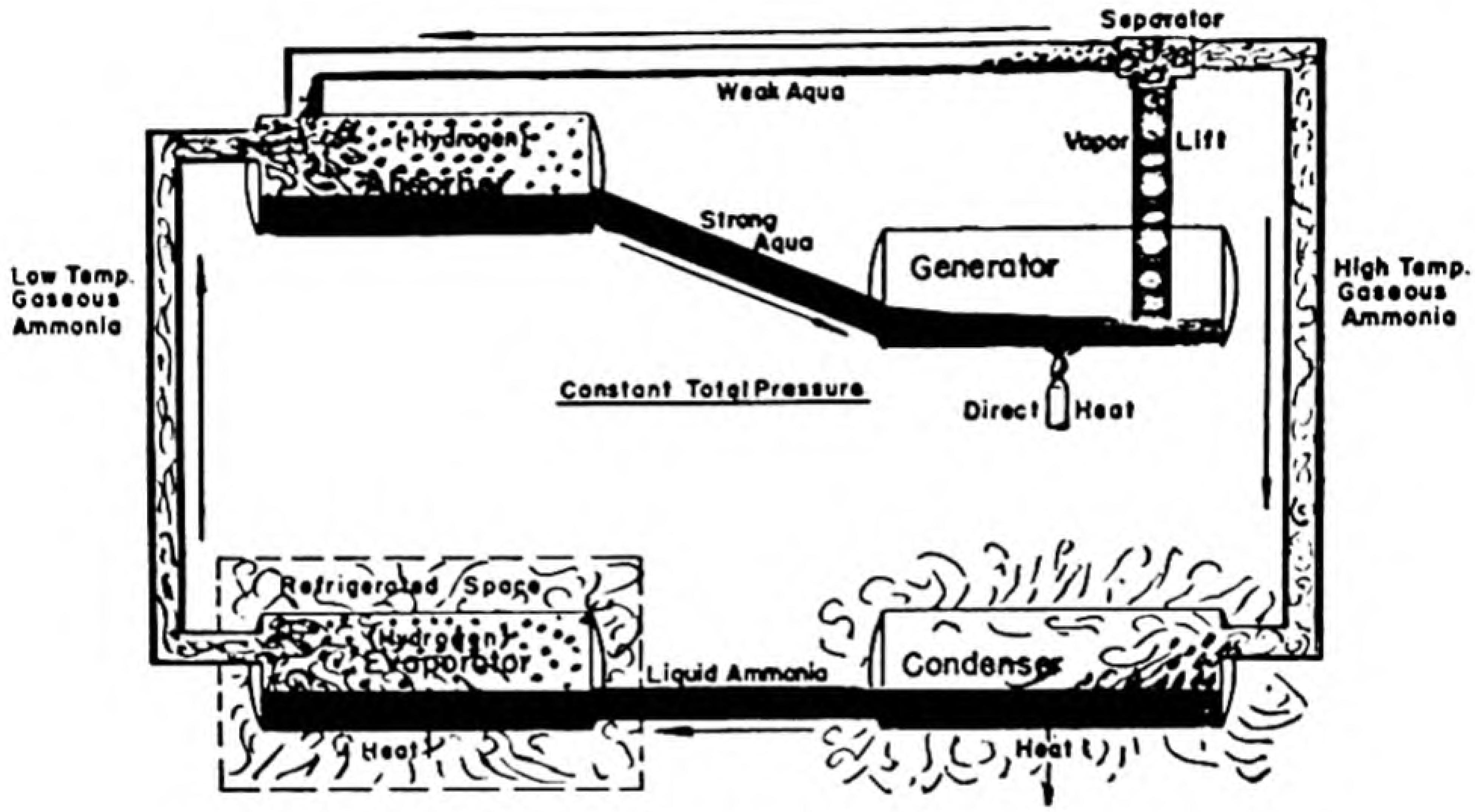

FIG. VIII

done by higher pressure in the generator, so a simple vapor lift, similar to that found in a coffee percolator is utilized.

This one-sentence paragraph and the figure were added as a result of the criticism of a reader that this portion was not clear. Do you think the additions satisfactorily solve the problem?

The result (Fig. VIII) is a continuous refrigeration machine using no valves, motors, or pumps, but motivated by a flame—"ice from heat."

The importance of the Platen-Munters features is emphasized by the fact that an American corporation paid five million dollars for their U.S. patent rights.

Since that time, a highly improved form of their machine has been developed, a machine unique in its valveless, pumpless control of fluids within a hermetically sealed

space. It contains three interrelated fluid circuits, rotating in unison to produce continuous refrigeration, powered by nothing more than a single small source of heat. As shown in Fig. III, the three circuits consist of the ammonia loop, the ammonia-hydrogen loop, and the ammonia-water loop.

The process is shown diagrammatically and much simplified in Fig. IV. Beginning with the ammonia-hydrogen loop, the ammonia gas enters the evaporator from the condenser through the liquid trap which confines the hydrogen to its own circuit. In the evaporator it takes up heat from the sur-

space. It contains three interrelated fluid circuits, rotating in unison to produce continuous refrigeration, powered by nothing more than a single small source of heat. As shown in Fig. IX, the three circuits consist of the ammonia loop, the ammonia-hydrogen loop, and the ammonia-water loop.

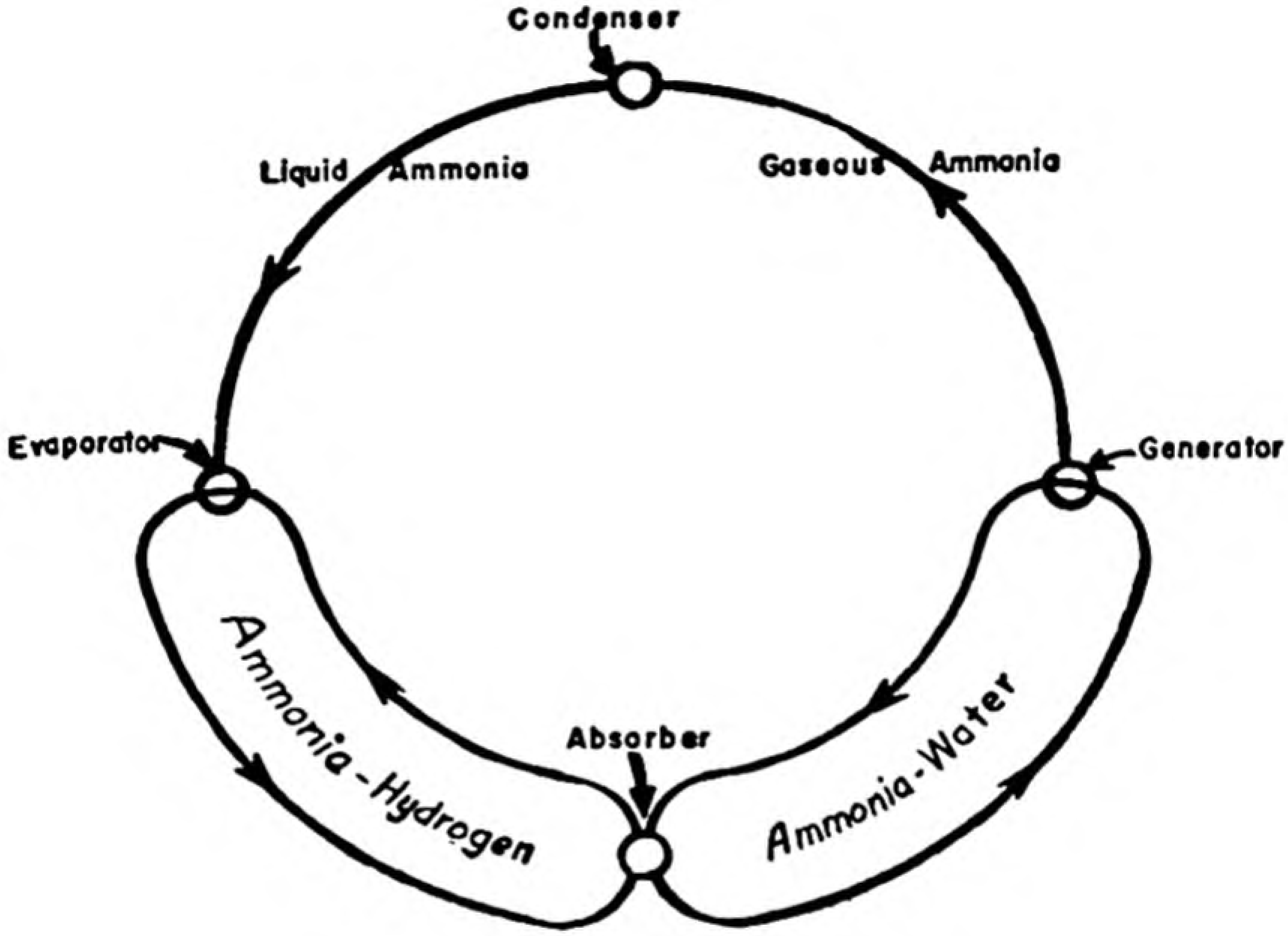

FIG. IX

The process is shown diagrammatically and much simplified in Fig. X. Beginning with the ammonia-hydrogen loop, the ammonia gas enters the evaporator from the condenser through the liquid trap which confines the hydrogen to its own circuit. In the evaporator it takes up heat from the surrounding space and vaporizes, its gaseous molecules mixing with those of the hydrogen. The addition of the heavier ammonia molecules increases the specific gravity of the vapor, and it sinks down the tube leading to the absorber.

In the absorber, the ammonia dissolves in the countercurrent stream of weak aqua,

rounding space and vaporizes, its gaseous molecules mixing with those of the hydrogen. The addition of the heavier ammonia molecules increases the specific gravity of the vapor, and it sinks down the tube leading to the absorber.

In the absorber, the ammonia dissolves in the countercurrent stream of water, while the practically insoluble hydrogen, lightened of its burden of heavy ammonia molecules, ascends to the evaporator to again perform its task of mixing with and decreasing the partial vapor pressure of the ammonia.

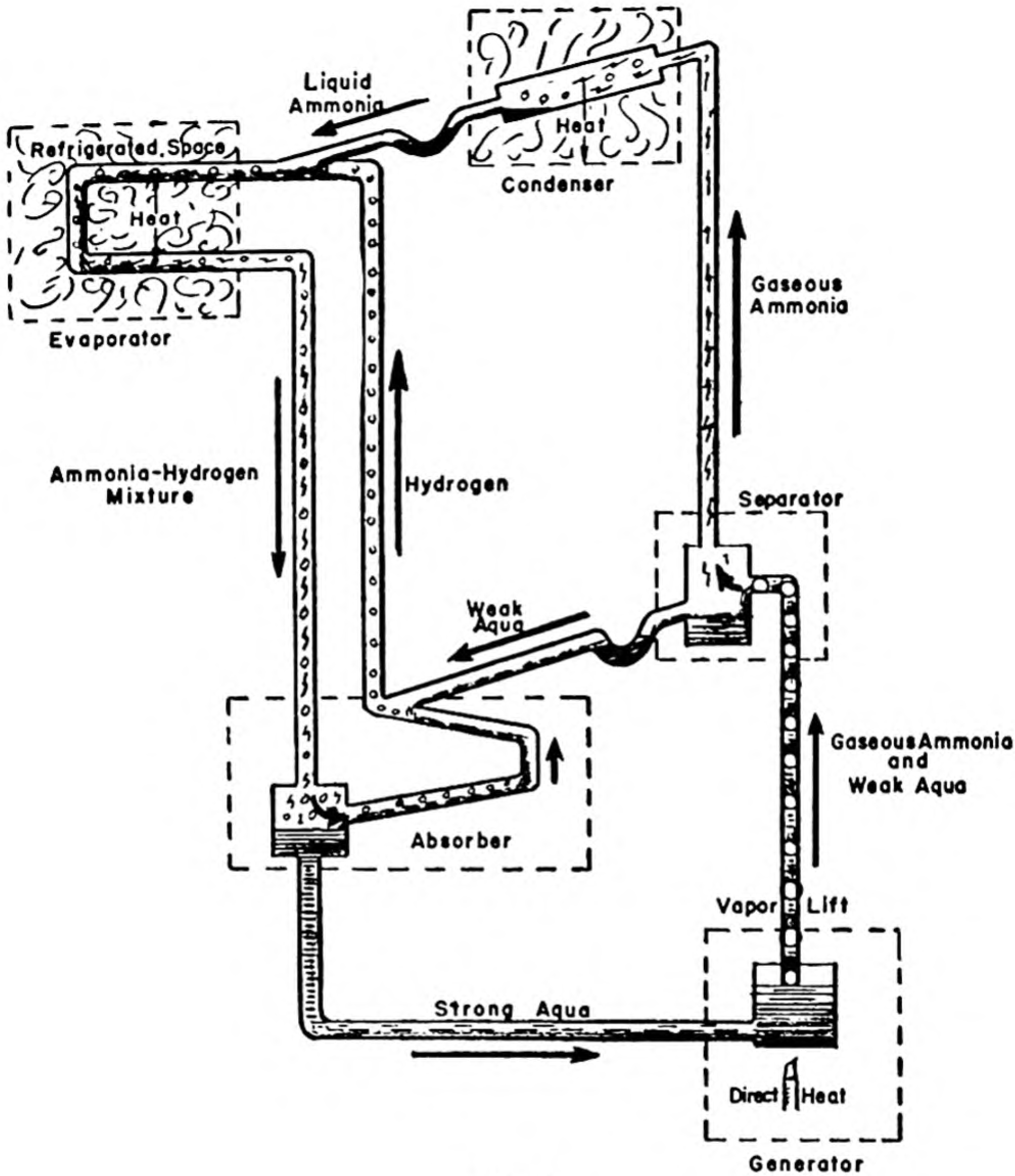

FIG. X

while the practically insoluble hydrogen, lightened of its burden of heavy ammonia molecules, ascends to the evaporator to again perform its task of mixing with and decreasing the partial vapor pressure of the ammonia.

Taking up the ammonia-water loop, the strong solution of ammonia in water, called "strong aqua," flows by gravity to the generator, where the application of heat drives the ammonia out of solution. A vertical tube, the inside diameter of which is equal to that of the bubbles of gaseous ammonia generated, projects below the surface of the boiling liquid, so that as the bubbles ascend the tube they carry up with them slugs of the solution. This "liquid lift" empties into the separator, where the ammonia vapor is separated from the weak solution of ammonia in water, known as the "weak aqua." The weak aqua then returns by gravity to the absorber to pick up another load of ammonia.

He leaves the word "sensible" here out of the revision, an omission which changes the meaning. Sensible heat is measured by a thermometer; latent heat changes the state of a substance without changing its temperature.

Finally, the ammonia loop, which has been traced as far as the separator, next involves the "condenser," an air-cooled heat exchanger which removes the sensible and latent heat from the ammonia gas, converting it into a cool liquid. Here it passes through the liquid trap that marks its re-entry into the evaporator to serve its purpose in cooling the refrigerated space.

Reference is made here to those refinements which are not shown or discussed. Compare with the final draft.

Not shown or discussed are the several refinements that go to produce the maximum of efficiency in this refrigerating process such as the heat exchangers that shunt the sensible heat of the several streams around to where it is most useful, the "analyzer" and "rectifier" that decrease the moisture content of the gaseous ammonia leaving the separator, and the "hydrogen reserve vessel" that balances change in atmospheric temperature with change in the total internal pressure on the system.

Industrial applications of the absorption refrigeration system include appropriate large-scale refinements, such as that engineering triumph of chemical processing, the bubble tower, which replaces with unmatch-

Taking up the ammonia-water loop, the strong aqua in the absorber flows by gravity to the generator, where the application of heat drives the ammonia out of solution. A vertical tube, the inside diameter of which is equal to that of the bubbles of gaseous ammonia generated, projects below the surface of the boiling liquid, so that as the bubbles ascend the tube they carry up with them slugs of the liquid. This "liquid lift" empties into the separator where the ammonia vapor is separated from the weak aqua. The weak aqua then returns by gravity to the absorber to pick up another load of ammonia.

Finally, the ammonia loop, which has been traced as far as the separator, next involves the "condenser," an air-cooled heat exchanger which removes the latent heat from the ammonia gas, converting it into a cool liquid. Here it passes through the liquid trap that marks its re-entry into the evaporator to serve its purpose of cooling the refrigerated space.

Here the refinements, while not discussed, are illustrated in a new figure not included in the earlier version. This serves, of course, to make his discussion clearer.

Omitted from the above discussion for the purpose of clarity, there are shown in Fig. XI the several refinements that serve to increase the efficiency of the machine, such as the heat exchangers that shunt the sensible heat of the several streams around to where it is most useful, the "analyzer" and "rectifier" that decrease the moisture content of the gaseous ammonia leaving the separator, and the "hydrogen reserve vessel" that balances change in atmospheric temperature with change in the total initial pressure on the system.

V. Conclusion

This version has been expanded slightly and the last sentence in the next to last paragraph definitely marks this as the conclusion of the paper.

Industrial modifications of the refrigerating system are many, varied, and equally interesting. They include appropriate large-scale refinements, such as that engineering triumph of chemical processing, the bubble

able efficiency the analyzer and rectifier of the Platen-Munters machine.

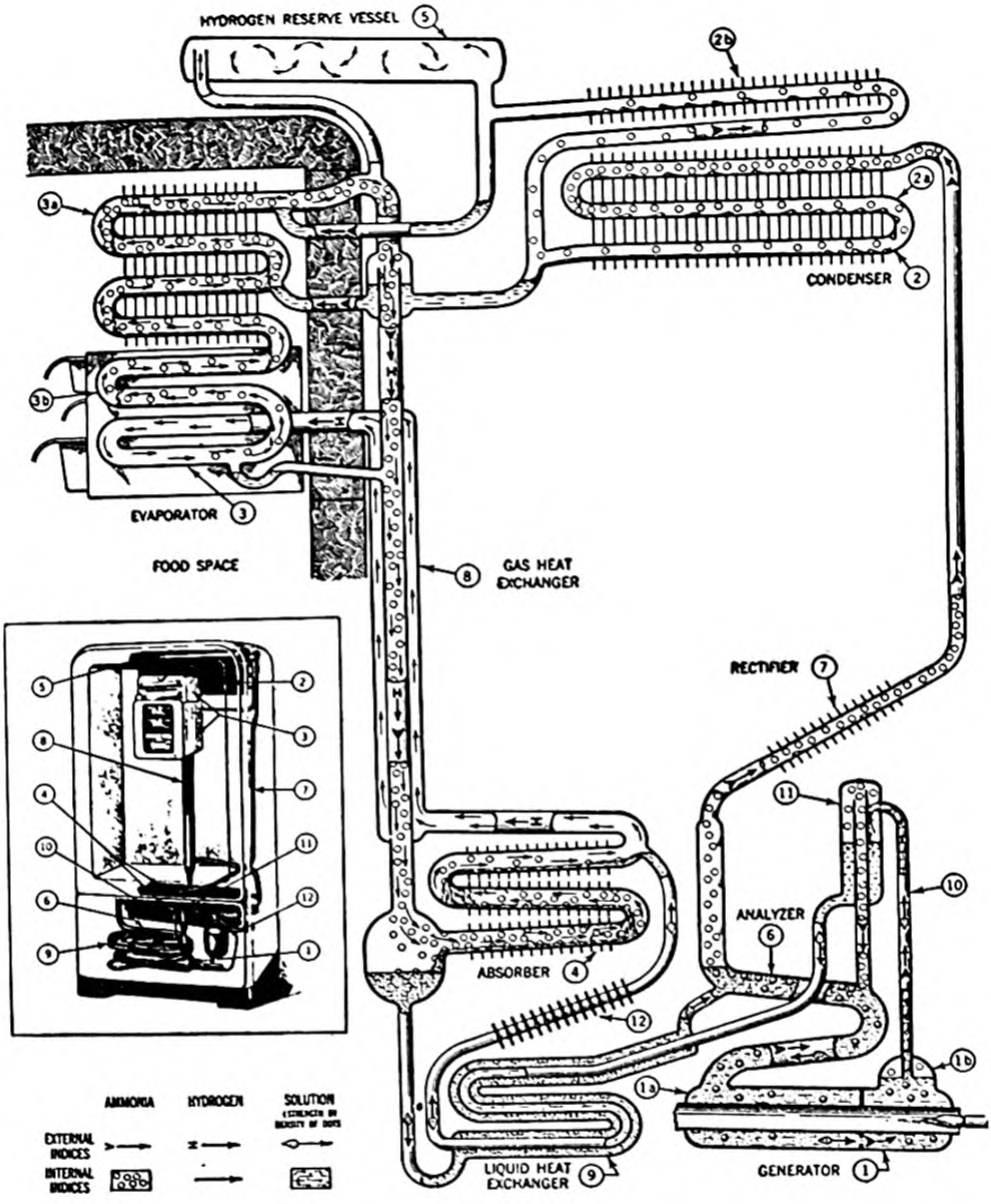

FIG. XI

tower, which replaces with unmatchable efficiency the analyzer and rectifier of the Platen-Munters machine. Limitations on the scope of this paper prevent further elaboration, but it is hoped that the evolution of

There is something of the same quality in this conclusion that was noted in the introduction—a certain bluntness and suggestion of haste. Note that considerable change has been made in the revision.

Further advances undoubtedly lie in the future, but there is little possibility that they will ever overshadow the significance of the developments that have reduced the price of a valuable commodity to one thousandth of 1 per cent of its onetime cost, and earned undying fame for two young Swedish students.

the artificial ice-making machine has already been traced far enough to assist the reader toward an understanding and appreciation of the resourcefulness that made it possible.

Note that in both versions, he has neatly tied his conclusion to the lead of his introduction—the startling reduction in the cost of ice.

The frontiers of science are wide, its horizon unlimited. Possibly it is not frequent that the engineer can point with pardonable pride to such a feat as the reduction of the price of an everyday necessity to one one-thousandth of 1 per cent of its onetime cost. But he thrives on the meat of research and development, and as long as there is an unsolved problem standing in the way of the advance of science, there will be a place for the engineer.

By way of summary, we may note several differences between the first and second versions. There are probably not so many differences between these two versions as one would normally expect because the earlier version is by no means the first draft of his report and because he has spent a good deal of time on the subject matter in preparing the oral version. Even so, we note the addition of figures for clarity, more careful transitions (including the use of headings), the polishing of style in several places, and the addition of some concrete details.

It is also significant to note the differences between the report and the oral version:

1. The tone of the oral version is more sprightly, more conversational. In the report, for instance, there is no mention of the pleasure of speculating about the spending of a million dollars—such a lead would not be suitable in tone and dignity for a report.

2. In the oral version, Galt often tells his audience what he is doing, as "Let's look at some of the aspects of this science . . ."

3. There is more detail in the written version.

4. There are more personal pronouns in the oral version, and more comparisons drawn from everyday experience to clarify points.

5. There are some differences in arrangement, or organization. See pages 401-405 of the report and pages 386 to 389 of the oral account.

6. There are more illustrations in the report.

7. The discussion of absorption refrigeration is given in lighter terms in the oral version; he even uses a humorous illustration of a man hurrying the refrigeration process by applying a blowtorch to speed up formation of ice. In short, Galt realizes the effectiveness of the personal touch in giving a talk.

8. Background discussion of Dalton's law of additive pressures is omitted from the oral account.

9. Discussion of refinements is omitted from the oral version.

10. The oral version has a simpler, more dramatic conclusion.

appendix c

Partial Report Writing

The purpose of appendix c is to give you an opportunity to examine the kind of instructions on report writing that you might be issued on the job. The instruction pamphlet that follows, entitled Partial Report Writing, *is quoted by courtesy of The Texas Company. The partial report is a type of report used in The Texas Company.*

Naturally, instructions on report writing differ considerably from company to company, but those that follow may be regarded as fairly representative. This particular pamphlet is one given to young engineers in the Technical and Research Division of The Texas Company after their initial six months' to a year's service.

PARTIAL REPORT WRITING

INDEX

-1-

FOREWORD

The forms and instructions contained in this pamphlet, regarding Partial Report writing, are given for and are expected to serve as guides for the preparation of complete and adequate Partial Reports. They are not to be misconstrued as absolutely binding in each and every case inasmuch as it is realized that the reports from the several departments of this Laboratory differ widely in nature of material to be reported. Neither is it desired to eliminate the characteristics and initiative of the individuals writing the reports. In reading this material, therefore, it should be clearly understood that the information contained therein is solely a guide offered to improve the organization of the reports and standardize the general form as much as possible.

-2-

PARTIAL REPORT WRITING

INTRODUCTION

For the purpose of standardizing as much as possible the forms of the Partial Reports written by the various departments in the Research Laboratory, it has been considered desirable to provide a general form and set of instructions for the preparation of all Partial Reports issued by this organization.

In general, the object of any report is first to convey to the reader the methods and results of any particular investigation of research. The report must, therefore, be written in such a manner that it will convey to the reader the material contained therein. In this respect, it is imperative that the report be written entirely from the viewpoint of the reader and be clearly intelligible to him. Next, a report is written to constitute a record of an investigation to which reference may be made by anyone at a later date. Each report then must be a complete record of the work performed and it should not be necessary at any time to refer to the original notebook for essentials. If such a reference is necessary, the report is not complete in the sense that it is self-contained, nor does it constitute a complete record of work performed.

The necessity of a high standard for all reports written by the Laboratory personnel cannot be

-3-

over-emphasized. In most instances it is impossible and/or impractical to have personal contact with the reader for whom the investigation is being conducted and the impression created by the particular research man is determined entirely by the character of the reports rendered. For this reason, extreme care and thoughtfulness must be exercised in drawing up these Partial Reports. Proper attention must be paid to the method of presentation, the order of development, the coherence of matter within the individual sections and paragraphs and finally proper emphasis must be given to the important points of the particular investigation. It is imperative that the data and results be so presented that no question of interpretation can arise in the mind of the reader.

In all cases the reports must be written in the third person.

-4-

ORGANIZATION OF THE PARTIAL REPORT

A good report should contain the following general subjects in the order mentioned:

I. Introduction

II. Report Proper

III. Conclusions

IV. Recommendations

V. Future Work

VI. Appendix

DETAILED PARTIAL REPORT

This heading, of course, covers the complete and unabridged data on the subject or phase of the subject under investigation, for which the report is written.

The form to be used for the normal Partial Report is illustrated below:

TITLE PAGE FORM FOR PARTIAL REPORTS

FIRST PAGE

HEADING

EXPERIMENT NO. TITLE

PARTIAL REPORT NO.___

__________Laboratory	Experiment No.___
__________Research Department	Estimate No._____
(Date of Writing Report)	Work Completed (Date)

SUBJECT OF REPORT

INDEX

SUBJECT	PAGE NO.

-5-

It should be understood that the above title page and index should be sent only to those receiving the complete report. (i.e. Report proper and appendix.) The title page and index should be identified using the letters O-A, O-B, etc.

On a new page following the index, heading should be as follows:

EXPERIMENT NO. TITLE

PARTIAL REPORT NO.___

_____________Laboratory	Experiment No.___
_________Research Department	Estimate No.____
(Date of Writing Report)	Work Completed (Date)

SUBJECT OF REPORT

The following comments on the Title Page Form are believed in order.

1. The report should show two dates: the one on the right hand side of the page being the date work was completed, and the one on the left hand side of the page the date the draft of the report was approved by the supervisor, and NOT the date of typing or issuance.

2. The index should include all the titles of the various important subdivisions of the report together with the page numbers on which they can be found. This part of the report is very necessary in that anyone referring to the report for a particular phase of the work may locate same with a minimum of effort and time. The page numbers will be supplied by the typist after the report has been typed.

3. The various titles, subdivisions and their designating letters or numbers should be identical with those same items contained in the report proper.

4. The usual indentation method for differentiation between the headings and subheadings should be used.

-6-

ORGANIZATION FORM FOR PARTIAL REPORTS

I. INTRODUCTION

A. Object
B. History
C. Comparison of present and proposed products, methods of processing or other such information
D, E, etc., - Other pertinent information deemed necessary.

II. EXPERIMENTAL WORK (Detailed Report)

A. Preliminary Investigation
   1.
      a.
B. Stocks used
   1.
   2. etc.
C, D, E, etc., for additional necessary phases

III. CONCLUSIONS

1.
2. etc.

IV. RECOMMENDATIONS

1.
2. etc.

V. FUTURE WORK

1.
2. etc.

Initials of those receiving copy of report, but not appendix, should be inserted at this point.

The signature of ____________ should be placed here, i.e.

APPROVED: ________________

-7-

Each report will have an appendix which will not have the same distribution as the report proper. Therefore, before starting the appendix, a sheet should be prepared and numbered, containing the following information:

WORK DONE BY: Director or Supervisor, Ass't. Director, or Ass't. Supervisor, Chemists and Experimental Operators as case may be

Initials of those receiving copy of the report (i.e. Report proper plus appendix) should be inserted here.

VI. APPENDIX

It should be understood that the appendix will include: All tables, charts, diagrams, bibliographies, methods of test, explanations or detailed interpretations of data presented which are considered essential to the report as a whole but not of sufficient importance to include in the report proper. Indices covering contents of this section should be incorporated as part of the appendix and should be in sufficient detail to show where each individual table, chart, diagram, method of test, etc. may be found. In some instances, it may be desirable to include in the report proper such data to give the desired clarity and completeness.

DISCUSSION OF ORGANIZATION FORM FOR PARTIAL REPORTS

The object of each division of the report and what material it should contain together with the general comments on the form as a whole are given below:

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I. Introduction

The introduction of the report should include the object of the problem and the history or background of the work.

In any report the object should be a clear, brief and concise statement covering the ultimate results or conditions desired as a result of the proposed investigation. In addition, and when at all possible, it is very desirable that a statement be made covering the direct application of the problem when solved and the magnitude of the savings or earnings to be derived therefrom.

The history includes the origin of the problem, pertinent information concerning past work and comparison of present and proposed products, methods of manufacture, etc., which may be the subject of the report. Any pertinent references such as previous Partial Reports, letters or kindred material should be included in this section. It is also an important point to state just what calendar period the work in the report covers.

It should be remembered, however, that the Introduction should be as brief as possible consistent with completeness and clarity.

II. Experimental Work

Under this caption is reported all pertinent details of the work done during the investigation in question and should include information on stocks, equipment and pro-

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cedures used, operating conditions, products produced, tests on products, cost of manufacture, discussion of the work in general, etc. It should be borne in mind, however, that the detailed data on the above items should be placed as much as possible in the appendix rather than in the report proper, but due cognizance should be taken by the writer of the most desirable distribution of the data on these and other items between the report proper and appendix. It is realized that the above-mentioned items will not apply to every report, and it is to be understood that they are merely given as examples and not to be misconstrued as definite subheadings to be covered in every report. Where data are used to illustrate any points in question these data should also be included in the section given over to Tables, Batch Nos., etc.

Where a chart or diagram may add to the clearness and aid in the interpretation of the work, it should be placed in the report at the point of discussion rather than in the appendix of the report with the other tables of data, diagrams and charts. Such tables, diagrams and charts placed in the report should be placed opposite the proper reference and bound on the right hand margin.

In many cases an economic analysis of the problem is very desirable to properly bring out the value of the work. When this is necessary, this discussion should be included in this section of the report, but calculations and detailed explanations should be placed in the appendix.

This portion of the report should be given in chronological order and every point of moment thoroughly discussed so that there will be no question in the reader's mind concerning any part of it.

III. Conclusions

Inasmuch as the conclusions of any research are dependent upon the experimental work and the results obtained therefrom, this section naturally follows the Experimental Work. This part of the report together with the Recommendations, which will be discussed later, constitute the most important phases of a good Partial Report or any report for that matter. For this reason, the conclusions should be clear, concise and direct. It is very undesirable to discuss the reasons for a stated conclusion inasmuch as these should be obvious after reading the preceding portions of the report.

IV. Recommendations

The natural follow-up to the conclusion of a report are the recommendations. The same general comments made concerning the conclusions should apply to the recommendations as well. It should be emphasized, nevertheless, that clear-cut recommendations are very desirable and helpful to the reader. For this particular portion of the report it should also be mentioned that the utmost care and caution should be exerted in forming the recommendations so that all are feasible, logical and applicable in the

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field for which they are intended. Needless to say, many times the value of research work is lost in that the work has been built around some impractical and, at times, impossible recommended objective.

V. Future Work

If the problem is not completed, or if in the mind of the writer, there are still some phases of the work which should be cleared up by further investigation, a logical outline for further work should be included under this caption. This will enable the reader to keep posted on the trends of the work and allow him to make suggestions if he desires. Although this section of the report can be placed either before or after the recommendations, it will naturally follow the latter in most instances.

VI. Appendix

In this section all data sheets whether they be straight data, flow-diagrams, charts or other material of this general nature; together with discussion of same, methods of test, procedures, etc. should be included. All tables and other data should be arranged in a manner that makes for easy reference when reading the body of the report. Too often, insufficient thought is given to the preparation of tables of data and when referring to same considerable time and effort is necessary to determine the way in which they are to be interpreted. Be sure

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then that the tables or other data are readily understandable and easily followed. It is of considerable aid in comparing data to have the standard of comparison available for ready use on the same sheet. In every case the data sheet whether it be a table, diagram or chart should show a page number as well as an identifying number of its own.

MISCELLANEOUS COMMENTS ON THE ORGANIZATION FORM FOR PARTIAL REPORTS

1. The headings as illustrated under the above form should always be placed in the center of the sheet, and all subheadings should be placed at the right of the left hand margin line.

2. The following rules for the use of letters and numbers in differentiating between the various subdivisions are recommended:

a. Roman Numerals for the large divisions of the report

b. Capital Letters, Arabic Numerals and small case letters in the order named for further subdivision

c. Arabic Numerals and small case letters in parentheses may be used for still further subdivision

3. The following illustration should indicate the proper method of identification:

II. EXPERIMENTAL WORK

A. Stocks Used

1. Specialty Oils

a. Turbine Oil

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(1) Work Factor

(a) Run No. 1

(b) Run No. 2

2. Fatty Oils

a. Tallow Oil, etc.

4. In the Conclusions, Recommendations and Future Work the Arabic Numerals are used immediately following the Roman Numerals inasmuch as there is very little subdividing of these portions of the report and the former numerals are in general use in all types of reports.

If a summary is desired, the following should be of assistance.

SUMMARY

A summary is an important part of any well constructed report. In order to give this portion of the report the proper emphasis, it is placed ahead of the report proper. Although most summaries are included in the report as a component part, it is our custom to make the summary a separate and complete unit to accompany the report proper. This sort of summary was necessitated inasmuch as it was desired to distribute summaries to certain persons in the organization who were not interested in obtaining the entire report. The summary should not discuss any phase of the problem but should consist of brief, clear and concise statements covering the most important and pertinent phases of the subject under investigation. In

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addition, it should be written in such a manner that the reader, who may be relatively unfamiliar with the subject matter, can obtain the essentials of the problem with a minimum of effort and time.

An accepted form in the research laboratory, and the one to which all Partial Reports should conform as much as possible is shown below:

SUMMARY FORM FOR PARTIAL REPORTS

HEADING

EXPERIMENT NO. TITLE

SUMMARY FOR PARTIAL REPORT NO.___

Experiment No.___
Estimate No.__
Research Laboratory ____________________ Date ________

SUBJECT OF REPORT

INTRODUCTION

EXPERIMENTAL WORK

CONCLUSIONS

*RECOMMENDATIONS

*FUTURE WORK

*These two sections are interchangeable depending upon the subject of the report.

Although the above form appears self-explanatory, a few comments concerning it are considered necessary.

The date to be used for the summary is the same as that used for the detailed report.

The headings for the various sections of the summary, for example, Introduction, Experimental Work, etc. should be placed in the approximate position of the page as shown in the above form. It is to be pointed out also, that no lettering or numbering of the sections in the summary is necessary. Means of designating subdivisions within the various sections is entirely at the discretion of the writer of the report.

CONTENTS OF SUMMARY SECTIONS

INTRODUCTION

In most instances, the introduction of the summary will be identical with the introduction of the Partial Report proper. In certain cases, however, it may be advisable to shorten this section still further for the summary. The requirements for this part of the summary are already discussed on Page 8, under I. Introduction.

EXPERIMENTAL WORK

Under this heading, brief, clear and concise statements on the outstanding items covered in the body of the report should be made. These items should be given in a logical and orderly manner. It is very desirable and recommended that in this section of the summary, where at all possible, concrete examples of data to illustrate and substantiate the statements made, be used. This makes for

clearer understanding and easier digestion of the report by the reader. It must be remembered that in the summary there should be theoretically no discussion whatsoever. In some special cases, however, some discussion may be warranted, and when such is the case, this discussion should be held to the barest minimum in order to carry out the full significance of the summary - BREVITY.

CONCLUSIONS

RECOMMENDATIONS

FUTURE WORK

These three sections of the summary should be identical with the same sections in the Detailed Partial Report at all times. The significance attached to these items and the general discussion as to their content and arrangement have already been covered under the same heading of the main report, Pages 10 and 11.

appendix d

Approved Abbreviations of Scientific and Engineering Terms*

The approved abbreviations in this appendix are those for the more commonly used technical terms only. For a complete list of approved abbreviations, you should write for the American Standards Association pamphlet ASA Z10.1-1941. It is published by The American Society of Mechanical Engineers, 29 West 39th Street, New York 18, N.Y.

* Reprinted with the permission of the American Society of Mechanical Engineers.

ABBREVIATIONS

absolute....................abs
acre-foot...............acre-ft
air horsepower..........air hp
alternating-current (as adjective)................. a-c
ampere...................amp
ampere-hour ....amp-hr
Angstrom unit..............A
antilogarithm...........antilog
atmosphere .... atm
atomic weight...........at. wt
average...................avg
avoirdupois ....avdp
azimuth................az or α

barometer .... bar.
barrel.....................bbl
Baumé .... Bé
boiling point...............bp
brake horsepower..........bhp
brake horsepower-hour..bhp-hr
Brinell hardness number....Bhn
British thermal unit....Btu or B

calorie .... cal
candle-hour .... c-hr
candlepower............... cp
cent...................c or ¢
centigram..................cg
centiliter.................. cl
centimeter.................cm
centimeter-gram-second (system)................ cgs
coefficient...............coef
cologarithm............. colog
constant................const
cosecant .... csc
cosine .... cos
cotangent................. cot
counter electromotive force.................cemf

cubic......................cu
cubic centimeter....cu cm, cm^3 (liquid, meaning milliliter, ml)
cubic foot...............cu ft
cubic feet per minute......cfm
cubic feet per second........cfs
cubic inch...............cu in.
cubic meter.........cu m or m^3
cubic micron.....cu μ or cu mu or μ^3
cubic millimeter..cu mm or mm^3
cubic yard..............cu yd

decibel.................... db
degree................deg or °
degree centigrade............C
degree Fahrenheit............F
degree Kelvin...............K
degree Réaumur.............R
delta amplitude, an elliptic function.................dn
direct-current (as adjective).d-c
dozen.................... doz
dram...................... dr

electric..................elec
electromotive force........emf
elevation.................. el
equation.................. eq

farad...........spell out or f
feet board measure (board feet)...................fbm
feet per minute............fpm
feet per second.............fps
fluid...................... fl
foot...................... ft
foot-candle............... ft-c
foot-Lambert............. ft-L
foot-pound...............ft-lb

foot-pound-second (system) . fps
foot-second (see cubic feet per second)
free on board . . . . fob
freezing point . . . . fp

gallon . . . . gal
gallons per minute . . . . gpm
gallons per second . . . . gps
gram . . . . g
gram-calorie . . . . g-cal

hectare . . . . ha
henry . . . . h
high-pressure (adjective) . . . . h-p
horsepower . . . . hp
horsepower-hour . . . . hp-hr
hour . . . . hr
hour (in astronomical tables) . . h
hundred C
hundredweight (112 lb) . . . . cwt
hyperbolic cosine . . . . cosh
hyperbolic sine . . . . sinh
hyperbolic tangent . . . . tanh

inch . . . . in.
inch-pound . . . . in-lb
inches per second . . . . ips
indicated horsepower . . . . ihp
indicated horsepower-hour . . . . ihp-hr
inside diameter . . . . ID
intermediate-pressure (adjective) . . . . i-p

joule . . . . j

kilocalorie . . . . kcal
kilocycles per second . . . . kc
kilogram . . . . kg
kilogram-calorie . . . . kg-cal
kilogram-meter . . . . kg-m
kilograms per cubic meter . . . kg per cu m or kg/m^3
kilograms per second . . . . . . kgps
kiloliter . . . . kl
kilometer . . . . km
kilometers per second . . . . . kmps
kilovolt . . . . kv
kilovolt-ampere . . . . kva
kilowatt . . . . kw
kilowatthour . . . . kwhr

lambert L
latitude . . . . lat or ϕ
least common multiple . . . . . . lcm
linear foot . . . . lin ft
liquid . . . . liq
liter l
logarithm (common) . . . . log
logarithm (natural) log$_e$ or ln
longitude . . . . long. or λ
low-pressure (as adjective) . . l-p
lumens per watt . . . . lpw

maximum . . . . max
mean effective pressure . . . . . mep
mean horizontal candle-power . . . . mhcp
melting point . . . . mp
meter . . . . m
meter-kilogram . . . . m-kg
microampere . . . . μa or mu a
microfarad . . . . μf
microinch . . . . μin.
micromicrofarad . . . . $\mu\mu$f
micromicron . . . . . . $\mu\mu$ or mu mu
micron . . . . μ or mu
microvolt . . . . μv
microwatt . . . . μw or mu w
miles per hour . . . . mph
miles per hour per second . . . . mphps
milliampere . . . . ma
milligram . . . . mg
millihenry . . . . mh
millilambert . . . . mL
milliliter . . . . ml
millimeter . . . . mm

millimicron........$m\mu$ or m mu
million...............spell out
million gallons per day.....mgd
millivolt..................mv
minimum................min
minute..................min
minute (angular measure).....′
minute (time) (in astronomical tables)..................m
molecular weight.......mol. wt

ohm............spell out or Ω
ohm-centimeter.......ohm-cm
ounce.....................oz
ounce-foot...............oz-ft
ounce-inch..............oz-in.
outside diameter...........OD

parts per million..........ppm
pint........................pt
pound.....................lb
pound-foot...............lb-ft
pound-inch..............lb-in.
pounds per brake horse-power-hour....lb per bhp-hr
pounds per cubic foot.............lb per cu ft
pounds per square foot......psf
pounds per square inch......psi
pounds per square inch absolute................psia
power factor.....spell out or pf

quart.....................qt

reactive kilovolt-ampere...kvar
reactive volt-ampere........var
revolutions per minute.....rpm
revolutions per second......rps
root mean square..........rms

secant.....................sec
second....................sec
second (angular measure).....″
shaft horsepower...........shp
sine.......................sin
sine of the amplitude, an elliptic function...........sn
specific gravity...........sp gr
specific heat..............sp ht
spherical candle power......scp
square.....................sq
square centimeter..sq cm or cm^2
square foot...............sq ft
square inch..............sq in.
square kilometer..sq km or km^2
square meter........sq m or m^2
square micron..........sq μ or sq mu or μ^2
square millimeter.......sq mm or mm^2
square root of mean square..rms
standard..................std

tangent..................tan
temperature.............temp
tensile strength..............ts
thousand...................M
thousand foot-pounds....kip-ft
thousand pound............kip

versed sine................vers
volt........................v
volt-ampere................va

watt........................w
watthour.................whr
watts per candle..........wpc
weight....................wt

yard......................yd

appendix e

Insect and Rodent Control

The material in this appendix is referred to on pages 48–52 of Chapter 4, "Outlines and Abstracts."

INSECT AND RODENT CONTROL*

Introduction

Flies, mosquitoes, and rats are the vehicles of infection for ten widespread diseases. Flies, which are mechanical carriers, are responsible for the transmission of the intestinal diseases, i.e., (1) typhoid, (2) paratyphoid, (3) dysentery, (4) cholera, and (5) hookworms. Mosquitoes spread diseases by biting; they are vectors in the cycle of transmission of (6) malaria, (7) yellow fever, and (8) dengue. Rats are the reservoirs of (9) plague and (10) typhus, but the rat's fleas are the vehicles of transmission.

There is but one way to stop the spread of these diseases, and that is to break the cycle of transmission. The best way to do this is to get rid of the insects and rodents, and the most effective method of getting rid of them is to remove their breeding places by good general sanitation. The only alternative is to kill the adults. Positive steps which may be taken in these operations are discussed below.

Breeding Control

As pointed out above, if there are no insects or rodents the diseases which depend on them for transmission must vanish. It is certainly cheaper and simpler to destroy their breeding places than to try to kill billions of adults only to find more billions waiting to be killed.

FLIES. One characteristic of the fly makes it particularly susceptible to breeding control. The fly always lays its eggs in decaying organic matter, preferably excreta or manure. Three stages in the life of the fly—the egg, larva, pupa—are spent in the manure. A minimum of eight to ten days is spent here before the adult emerges. Therefore, the measures are relatively simple. First, there should be proper sewage disposal, i.e., the flies are never permitted to come into contact with human excreta. Secondly, all animal manure should be removed within four or five days, or in other words, before pupation takes place. The manure should either be placed in fly-proof storage bins or tightly compressed so that the adult fly cannot emerge after pupation. The final breeding control is to destroy all decaying organic matter such as garbage by either burying it two feet deep or burning it.

MOSQUITOES. It is not as simple to control the breeding places of the mosquito as it is to control those of the fly. But it can be

* "Insect and Rodent Control" is Section IV of *Sanitation Requirements for an Isolated Construction Project*, by Jerry Garrett.

done! First, it must be realized that there are many kinds of mosquitoes and that only a few are disease vectors. Still they must all be killed to be sure the correct ones are dead, and they are all important as pests anyway. The female *Aedes aegypti* is the vector for yellow fever and dengue; this mosquito breeds only in clean water in artificial containers. In the southern section of the United States (the chief malaria area in the United States), the malaria vector is the *Anopheles quadrimaculatus*, a night biter, which breeds in natural places, particularly where the water is stationary and where there is vegetation and floating matter to protect the eggs, larvae, and pupae.

Therefore, the best way to prevent the breeding of mosquitoes is to remove all water in which they breed by draining or filling pools, and removing or covering artificial containers. However, since the construction project is only temporary, the operators will be interested in the most economical measures rather than the most permanent. Artificial containers must still be covered, but it might be cheaper to spread a film of oil over all the natural, stationary water rather than to try to drain it or fill in the low spots.

RATS. There are no direct ways to control the breeding of rats or their fleas, but sufficient control can be exerted to make them take their breeding elsewhere. This is done by building rat-resistant houses and by preventing the rats from reaching food.

Adult Control

FLIES. Houses should be screened to keep the flies from getting to food. Then, traps such as the standard conical bait trap should be distributed. The most attractive baits, as established by experiment, are fish scraps, overripe bananas, and a bran and syrup mixture. DDT may be used effectively to leave a residual poison for flies.

MOSQUITOES. If a house is well screened, the mosquitoes cannot get into the house to bite their victims. Advantage can be taken of the mosquitoes' natural enemies by stocking waterways with minnows which eat the larvae. Poisons which may be used against mosquitoes are DDT and pyrethrum.

RATS. Besides carrying diseases, the rat of course destroys much property. Usually, however, the construction project operator need be concerned with rats only to the extent that they endanger his workers' health. Poisons which may be used against rats are barium carbonate, red squill, 1080, and antu. Other effective means of getting rid of rats are by trapping and fumigation.

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[*Note: Page numbers in italics refer to illustrations and examples.*]

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